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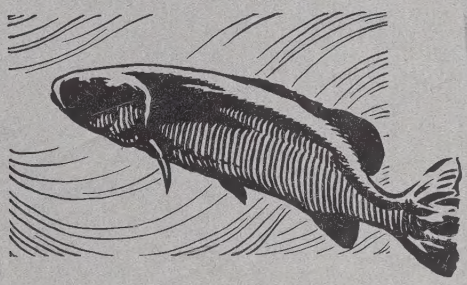

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AN EVALUATION OF SOME PHYSICAL AND MECHANICAL FACTORS IMPORTANT IN REDUCING DELAYED MORTALITY OF HATCHERY-REARED RAINBOW TROUT

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A STUDY OF THE POST-PLANTING DELAYED MORTALITY of yearling rainbow trout transported from four Oregon State Game Commission hatchery and rearing stations was conducted during the summer liberating season of 1954.

In Oregon the term "delayed mortality" is used to denote the trout deaths which occur during 1 to 7 days after liberation. Separate and apart from immediate hauling loss, delayed mortality generally can be expected to commence about 24 hours subsequent to release. After peaking on the third or fourth day, the loss pattern becomes one of gradual decrease and complete cessation within the 7-day period.

The investigation included two distinct phases. The function of this paper is to present an evaluation of the physical and mechanical factors tested; namely, water-temperature controls in transport, types of aeration devices, use of sodium amytal at the rate of 0.5 grain per gallon of water, and loading and unloading techniques for trout. D. W. Linn, with whom the study was jointly conducted, presented an analysis of the water chemistry and the changes encountered in the 84 loads studied.[1/]

History of the Problem

For at least 30 years, there has been awareness of delayed mortality following transfers of fish to certain Oregon trout hatcheries. Such losses were first noticed in rearing ponds newly occupied by fish from other stations. The pattern of occurrence was so erratic, however, that it was deemed neither feasible nor profitable at the time to devote the necessary effort or manpower to an inquiry into the difficulty.

Initial inquiries by personnel of the Oregon State Game Commission established the actuality of the problem in 1937. The pioneering work was interrupted in 1941; not until 1946, after World War II, did Game Commission biologists again take active interest in the matter.

The problem was assigned to the Oregon Cooperative Wildlife Research Unit in 1950. Preliminary studies were conducted the next year; and intensive field investigations were commenced in June 1952, when W. O. Saltzman and J. C. Simes

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The Oregon Cooperative Wildlife Research Unit is sponsored by the Oregon State Game Commission, Oregon State College, Wildlife Management Institute, and the U. S. Fish and Wildlife Service, cooperating.

1/ Linn, D. W. Delayed mortality of hatchery-reared rainbow trout in relation to five chemical factors encountered in transporting waters. Oregon State College, master's thesis, 73 pp. 1955.

inaugurated the work of which the current study is a continuation.

The geographic limitations of delayed mortality are unknown, but there are indications that the problem may reach well beyond the boundaries of Oregon. State fishery agencies in California, Arizona, Washington, and Idaho have at one time or another acknowledged a similar type of mortality in their artificially propagated trout, thus establishing its presence in other western States. Miller (1952), who worked with the survival of hatchery-reared cutthroat trout in Alberta, Canada, reported that losses among 2-year-old trout began on the day after planting and by the 14th day had risen to 46.8 percent. Stroud and Bitzer (1955), working with salvaged warm-water fish in Massachusetts, reported losses of 18.5 percent in yellow perch, 72 and 38 percent in smallmouth bass, and 50 percent in pickerel that died soon after stocking. Reports of this nature lead to the suspicion that delayed mortality may occur whenever fish are transported prior to release.

The cause of delayed mortality is evidently of a threshold nature, as it proves fatal to only a portion of the fish transported. Size makes no difference, as delayed mortality affects large and small alike. The percentage of deaths after any particular liberating trip can never be predicted accurately. Saltzman reported losses ranging from 0 to 93 percent in rainbow trout.[2/] The average delayed loss in Oregon may be as high as 10 percent of the fish transported.

Symptoms of Delayed Mortality

The indications of impending delayed mortality come in three stages. The first stage is a general nervousness or state of uneasiness. The fish school and swim in circles, with an occasional individual rising to nip at the surface of the water as though gasping for air or taking a small morsel of food. At this point, the fish are easily excited and often stampede at a sudden, unexpected motion in the water or nearby on shore. If unmolested, the fish may gradually reach the second stage; but often the period of intense activity is followed immediately by a loss of equilibrium, apparent blindness, and lack of coordination. The fish may swim rapidly in tight circles, attempt to jump out of the water, or plow head-down along the bottom of the pond. At times a recovery of faculties is evidenced--only to be lost a little later. The third stage comes slowly with a cessation of swimming, after which the fish float or sink. The mouth and gill covers open spasmodically, and slight tremors wrack the body; gasping becomes weaker and finally ceases with the advent of death. In most instances, the mouth remained completely distended and agape as though locked into position. Autopsy revealed a dark spot on the wall of the intestinal cavity adjacent to the gall bladder in about 15 percent of the cases. Symptoms similar to these have been described by Eicher (1946) as resulting from high pH in Arizona's high mountain lakes.

Methods and Apparatus

Saltzman concluded that delayed losses were an almost inevitable result of trout transportation operations.[2/] With this in mind, the approach to the current study was to simulate normal transportation methods under conditions in which the variables could be controlled and measured. The resultant delayed mortality was then compared with the variables in an attempt to find correlations.

In the 1954 studies, four different liberation trucks using two basic aeration principles were employed. The transported fish were rainbow trout, Salmo gairdneri Richardson, originating from four separate Oregon State Game Commission hatcheries. In 84 experimental hauls, the mechanical and physical factors were varied. These modifications were arranged into several designs for the

[2/] Saltzman, W. O. A preliminary study of certain chemical factors that may be involved in the delayed mortality of rainbow trout following liberation. Oregon State College, master's thesis, 59 pp. 1953.

purpose of statistical analysis. All data were tested by the analysis-of-variance method at the 95-percent confidence level.

Liberating Tanks

Two of the vehicles used in the study carried tanks that were aerated by an overhead-spray device. Copeland (1947) regarded aeration by spraying as highly efficient because the water, during its downward fall, gathered oxygen and simultaneously released carbon dioxide. The larger of the two units, hereafter referred to as tank A, held 250 gallons of water. A detailed diagram of this tank is presented in figure 1. The second overhead-spray unit, referred to as tank B, held 150 gallons of water. Figure 2 shows the essential components of the unit.

The other two fish-liberating tanks used in these experiments were equipped with venturi-type aerators. Tank C, the California-type unit, had a capacity of 150 gallons. Venturi tanks need no air space above the surface of the water for spraying. Leitritz (1950) described tank C in detail. The side-delivery venturi tank, tank D, which had a capacity of 175 gallons, is illustrated in figure 3.

Standardized Hauls

In order to attain comparable transportation conditions for each experiment, a standardized haul was established as follows: Each truck was assigned a permanent driver for each sequence of tests. Water for the liberation tanks was obtained from the hatchery source at the station of operations. Fish used for each haul had not previously been transported and were starved 48 hours in advance. Except in Experiment IV, each tank was loaded with 3 pounds of fish per 5 gallons of water. Simulated 6-hour planting hauls were made. From these hauls the trucks returned to the hatchery of origin, where the fish were uniformly discharged into individual ponds for a 7-day observation period. The trucks moved in caravan style, maintaining the same order of procession while filling with water, loading fish, traveling enroute, and discharging. At 30-minute intervals the trucks were stopped in order that the temperature of the water in the tanks could be checked. The desired water temperatures were maintained by the addition of ice chipped from cakes carried on the outside of the trucks.

Location of Hatcheries

The Cascade Range divides Oregon into eastern and western sections. Four basic experiments conducted involved two low-altitude, river-fed hatcheries that were west of the Cascades and two high-altitude, spring-fed hatcheries that were on the eastern side. The Roaring River and Leaburg hatcheries were situated to the west, and the Klamath and Wizard Falls hatcheries were on the eastern side of the range.

Uncontrollable Variables

1. Strain of fish transported.--"Catchable" trout were used in all experiments. At the Roaring River, Leaburg, and Klamath hatcheries, the propagated fish were fall-spawning rainbows. The early spawning stock from the Wizard Falls hatchery were generally smaller and appeared more vigorous than the trout from the other stations.

2. Hatchery diets.--The diets fed to the transported fish varied among the four hatcheries. The kind, quantity, price, and availability of the several food items used accounted for the variability noted. Approximate percentages of meal and meat in each diet are shown in table 1.

TABLE 1.--Approximate percentages of meal and meat in the hatchery diets

Hatchery	Meal	Meat
Roaring River	25	75
Wizard Falls	5	95
Leaburg	17	83
Klamath	17	83

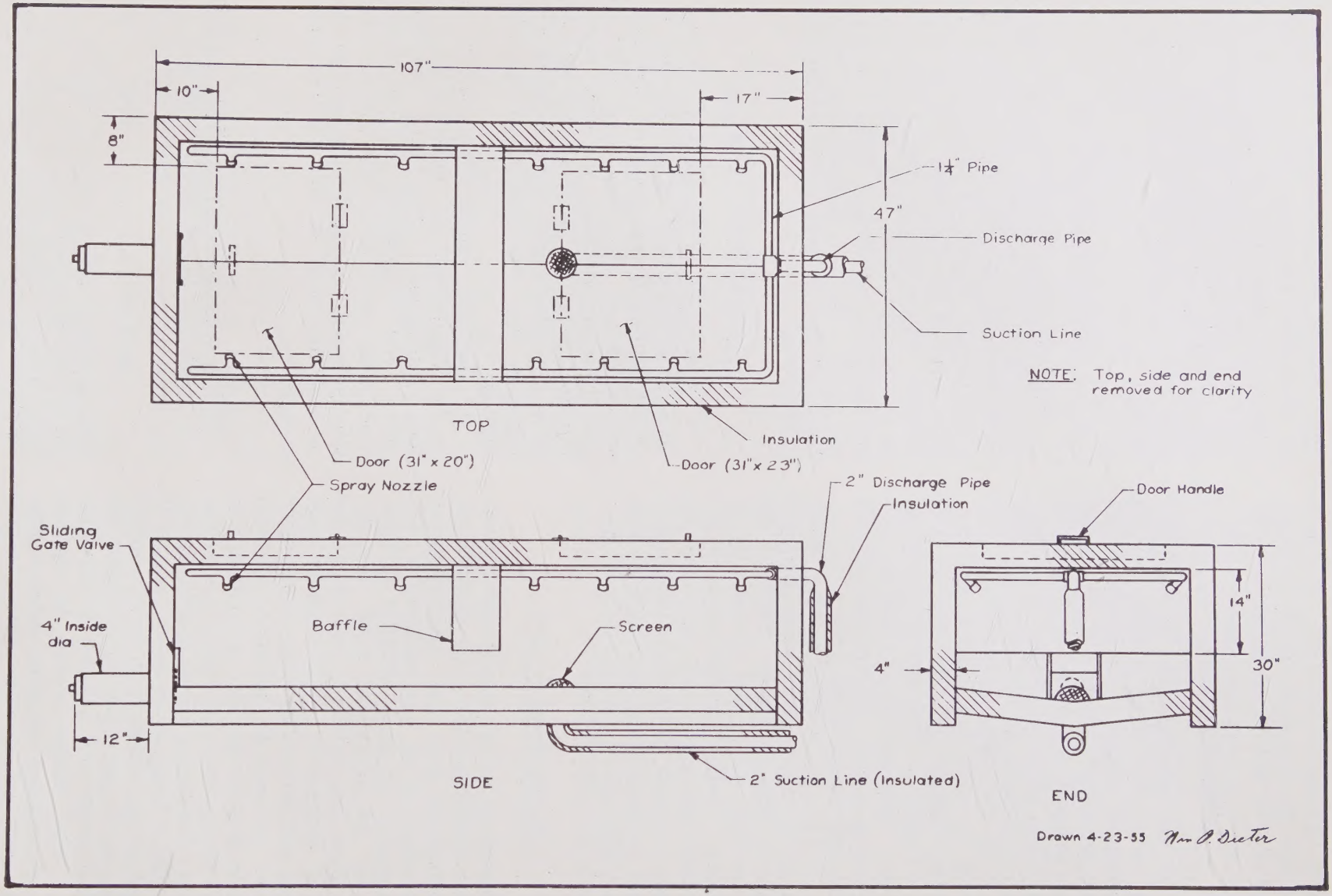

FIGURE 1.--Detail of tank A.

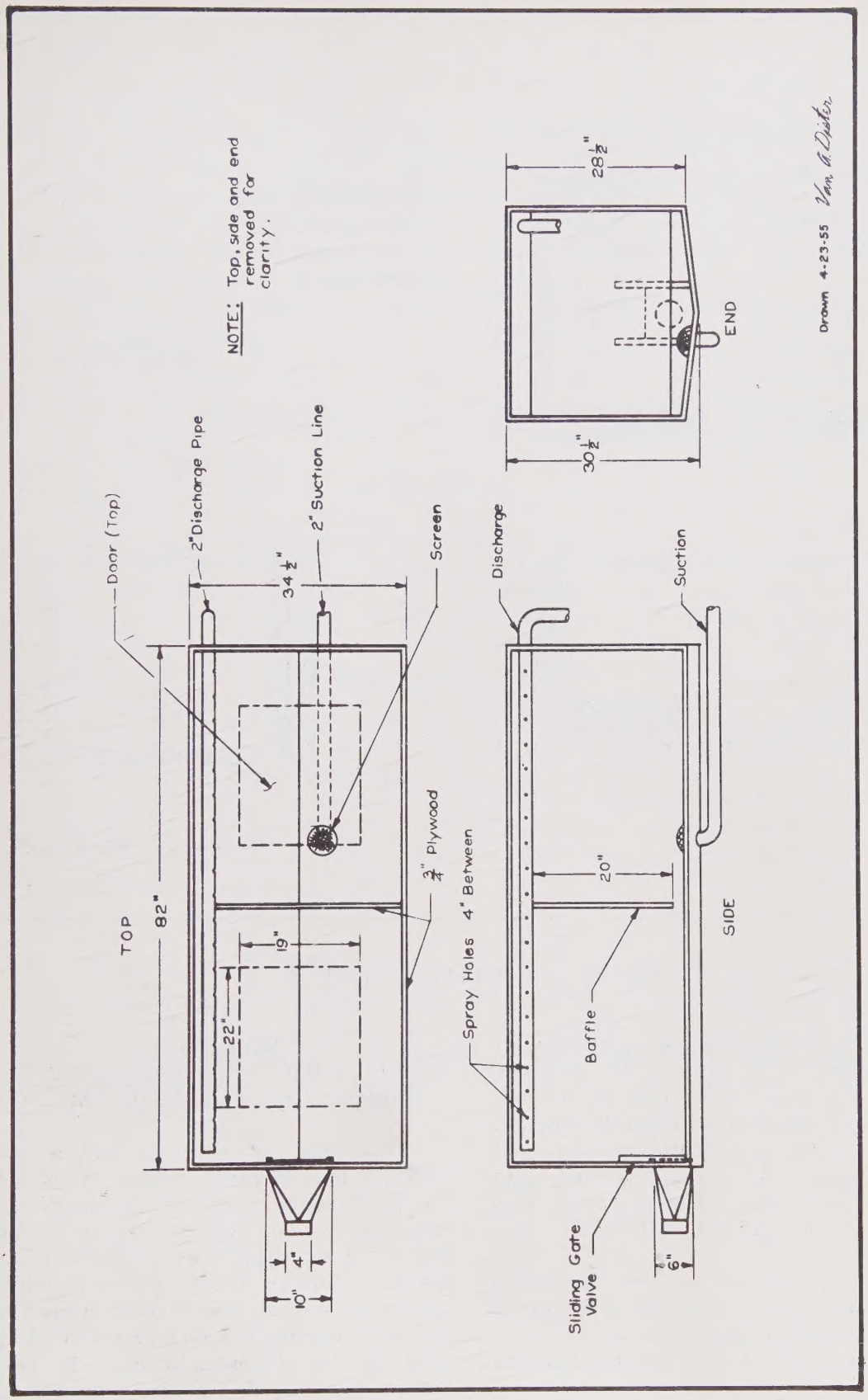

FIGURE 2.--Detail of tank B.

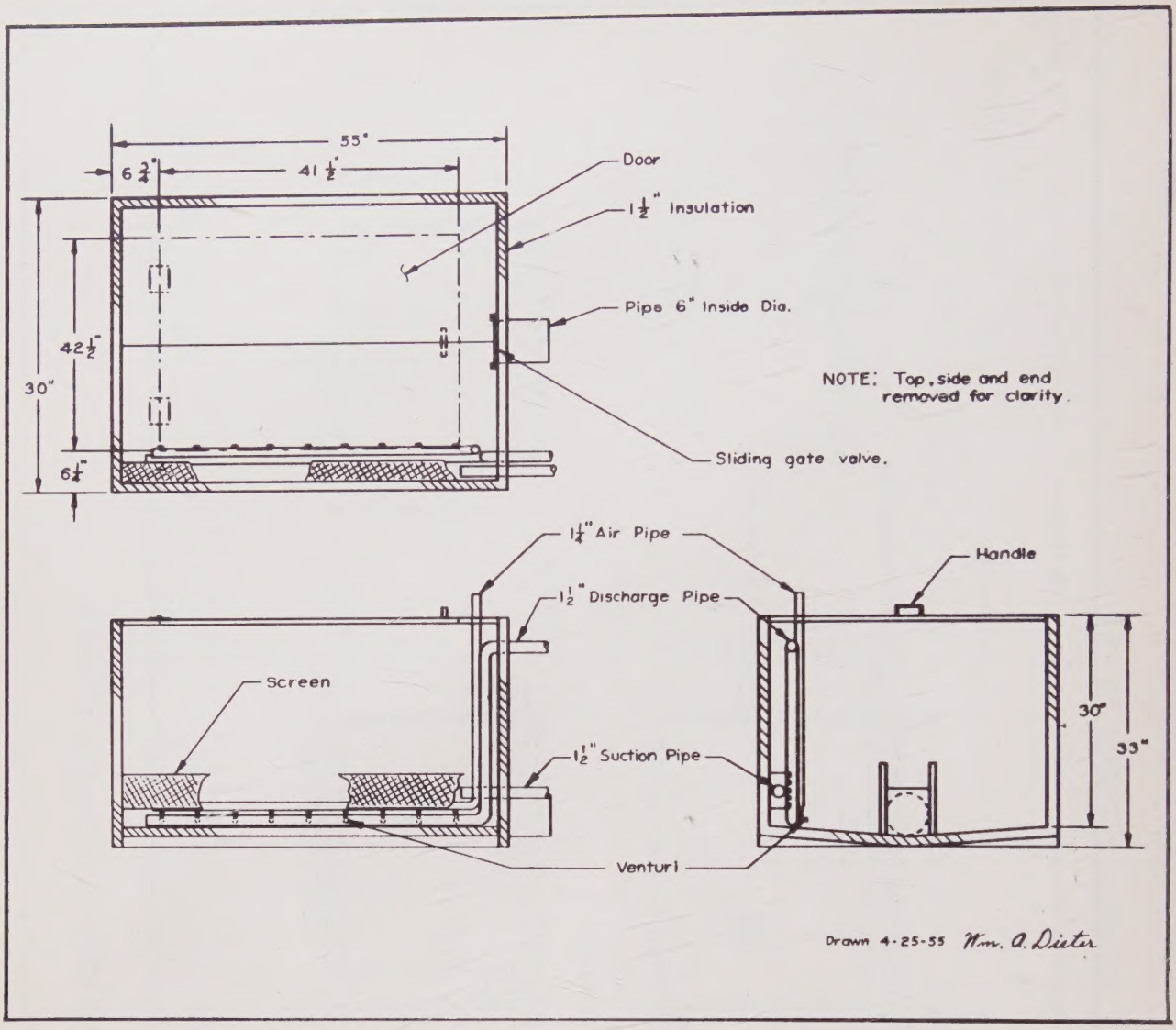

FIGURE 3.--Detail of tank D.

3. Hatchery location and water supply.

4. Changes with time. --As summer advanced, the size of the fish increased, the number of hours of daylight decreased, and air and water temperatures underwent steady changes. As no correlation with time could be found, it is assumed that these variations did not affect the test results.

There were other minor variables not mentioned here, but it is believed that their common existence at all four stations tended to efface any pronounced effect.

Experiment I
Effects of Water Temperature and Type of Aeration Device on Delayed Mortality

According to Phillips and Brockway (1954), for several years it has been thought that the metabolic products of trout might be the limiting factors in establishing carrying capacities of holding equipment. Another limiting factor might be shock caused by accelerated activities of the fish during loading and unloading as well as the transportation. If delayed losses are due to lethal concentrations of

metabolic products or to a neuro-physical shock, it would seem logical to effect a control of these by reducing the rate of metabolism of the fish.

Water temperature has long been recognized as a chief factor in regulating the metabolism of fish in nature. With this in mind, an experiment was designed to test the influence of water temperature on delayed mortality. By utilizing a factorial design, it was possible to test simultaneously the influence of types of aeration systems on delayed losses.

The values of 40°, 47°, and 55° F. were picked to represent low, medium, and warm temperatures usually encountered in transporting trout. Tanks A, B, and C were selected because they represented three different kinds of liberating units. Each level of water temperature was carried twice in each tank during a 6-day period. No two tanks carried the same temperature on a single day.

The experiment was conducted first at the Roaring River hatchery and repeated the following week at Wizard Falls. The resultant percentages of delayed loss for each tank at each temperature are presented in table 2 for the Roaring River station and in table 3 for Wizard Falls.

The arc-sine-square-root-of-the-percentage values were computed to help to equalize the variance caused in the three tanks by the difference in their capacities. The factor of temperature proved to be of significance in both experiments, the high mortality rate being associated with the hauls at high temperatures. Low temperature, in this case, was not the cure for delayed mortalities, but the control. By lowering the water temperature, the metabolic processes were slowed, reducing the production of toxic substances and making the fish less susceptible to shock.

The difference due to tanks was significant only in the test made at Roaring River. Delayed loss of fish transported in units aerated by overhead spray averaged much higher than delayed loss of fish that were carried in venturi tanks. The higher rate of loss in the overhead-spray units is believed to be due to the design of the tank and aeration system. Owing to the need for an area above the surface of the water for the spraying, a great deal of surge and sloshing within the compartments of the tanks was caused by the stopping, starting, maneuvering, and jostling of the trucks over various types of roads. The constant change in direction and force of the water not only caused some physical injury to the fish, but also kept them in a continual state of excitement and activity which prolonged the high metabolic rate. Also, it is possible that the fish received additional physical abuse upon coming in direct contact with the water that was

TABLE 2.--Percentages of delayed loss in experiment testing influence of water temperature and type of aeration system on trout transported from Roaring River hatchery, June 28-July 3, 1954

Tank	55° F.	47° F.	40° F.	Mean
A--------	23.32 8.83	0.82 .82	0.07 .18	5.67
B--------	15.58 6.82	8.78 .30	.58 .29	5.39
C--------	.58 .15	.23 .29	.17 .39	.30
Mean---	9.21	1.87	.28	3.79

TABLE 3.--Percentages of delayed loss in experiment testing influence of water temperature and type of aeration system on trout transported from Wizard Falls hatchery, July 7-12, 1954

Tank	55° F.	47° F.	40° F.	Mean
A--------	0.45 .47	0.21 .24	0.00 .20	0.26
B--------	.44 .70	1.00 .22	.11 0	.41
C--------	.23 .22	0 .11	.13 0	.12
Mean---	.42	.30	.07	.26

ejected from the spray nozzles under considerable pressure.

The venturi tank was relatively free from these disadvantages. The design of the aeration system allowed the complete filling of the tank and a subsequent reduction of the surge and sloshing. By admitting the circulated, oxygenated water at the rear of the tank and sucking it out at the front, a definite current was established within the tank, allowing the fish a means of orienting themselves. Use of the venturi aeration also eliminated any possibility of injury to the fish from spraying.

The large difference in the extent of the delayed mortalities for the two hatcheries is possibly explained by the strain of fish transported and the percentages of meal and meat in the diets. Schuck (1948) and Wales (1954), reporting on the survival of hatchery trout, left little doubt that condition of fish is a primary determining factor of survival. As mentioned earlier, the spring-spawning fish from the Wizard Falls hatchery appeared in better condition than the fall spawners from Roaring River. The larger percentage of meat and fish products fed at Wizard Falls may have accounted for this difference. Hess (1935) showed that degeneration of the pancreas may possibly be induced by the addition of fat, or fat and carbohydrate, to the diet of hatchery-reared trout. Schuck (1948) offered, as being among the possible causes of low survival ability of hatchery-reared trout, the following: High percentage of fats and carbohydrates in diets, overfeeding, lack of exercise, no necessity to forage for food, freedom from predators, stable water temperatures all year round, domestication of brood stock, selection of brood fish for hatchery performance, absence of natural food, and methods of transporting and hauling. Because the fall spawners have been subjected to the hatchery domestication for a longer time, it is felt that reasoning such as this substantiates the hypothesis that the survival potential of the Wizard Falls fish exceeded that of the fish from Roaring River.

Experiment II
The Effects of Sodium Amytal on Delayed Mortality

Low water temperature in transportation, though an effective means of controling delayed mortalities, is not easily maintained by the use of ice. During the first 18 hauls of Experiment I, an average of 223 pounds of ice was used in each tank each day. Not only was the ice inconvenient to carry on the trucks and heavy to handle, but sometimes a nonchlorinated supply was hard to find. In an effort to dispense with this problem, it was decided to test the effectiveness of a hypnotic drug as a means of reducing delayed mortality.

On the basis of the findings of Reese (1953), who developed a method of increasing the payload of air-transported fish, sodium amytal was selected for use in every haul at the rate of one-half grain per gallon of water. The experiment was run at the Roaring River hatchery. Two B-type tanks were used. Each tank carried water controlled to 47° and 55° F. twice, although the temperature was not the same in the tanks on any one day. The venturi-type aeration tank and the 40° F. water-temperature control were eliminated from the experiment in view of their proved ability to reduce delayed losses. The experimental results are shown in table 4.

There was no significant difference between the percentage of mortalities shown in table 4 and those from the overhead-spray loads at 47° and 55° F. shown in table 2. It is therefore concluded that the sodium amytal is not effective in reducing delayed mortalities at Roaring River station.

The failure of sodium amytal to be effective at 55° F.

TABLE 4.--Percentages of delayed loss in the sodium amytal experiment, July 20-30, 1954

Tank	55° F.	47° F.
B_1------	23.57	4.82
	27.57	.83
B_2------	10.06	3.42
	15.98	2.09
Mean--	19.30	2.79

has been explained by Rayner, who stated that at 52° F. the drug loses its effectiveness and at 55° is lost completely.[3/] The failure of the drug to reduce delayed loss at 47° F. has possibly been explained by Phillips and Brockway (1954), who found that the action of sodium amytal was delayed between 4 and 6 hours.

There was once again a significant difference due to temperature. That the high temperature reflected the high mortality, and vice versa, helped strengthen the conclusion drawn from Experiment I.

Experiment III
The Effects of Loading and Unloading Techniques on Delayed Mortality

The testing methods used at the two hatcheries in Experiment I were essentially the same except for loading and unloading techniques. Because the ponds were dirt bottomed, the fish at the Roaring River hatchery were collected for loading by use of a seine. In the netting operation, much of the decaying organic matter on the pond bottom was collected with the fish. The fish were held in this foul medium until dipped with a rubber net into tubs for weighing and loading. At the end of the standardized 6-hour haul, the fish were dipped from the liberating tanks into buckets, carried short distances to the observation ponds, and released.

At the Wizard Falls hatchery, cement-bottomed ponds permitted the use of gate-type crowders to collect fish for weighing and loading. This method is superior because the fish are not held in a concentration of decaying feces and fish food prior to loading. Upon completion of the standardized 6-hour haul, the fish were discharged by hose into conveniently located observation ponds. Unloading by "hosing" is considered easier on the fish because it is quicker and does not require handling them.

In Experiment I, the overall intensity of mortalities was much greater at the Roaring River hatchery than at the other trout station. To determine whether the superior survival rate at Wizard Falls was influenced by the relatively gentler loading and unloading techniques, the rougher methods used at Roaring River were tested at Wizard Falls. The results of this test appear in table 5.

There was no significant difference between the percentages shown in table 5 and those from the overhead-spray loads at 47° and 55° F. in table 3. Temperature, in this case, did not follow the same correlation that had been noted previously.

When rougher loading and unloading techniques did not increase delayed losses at Wizard Falls, a test was run to determine whether more gentle methods would decrease mortalities at Roaring River. The more gentle procedure involved transferring the fish to an old-fashioned rod-type grader so that they rested in clean water while awaiting weighing and loading. At the end of the 6-hour haul, the fish were discharged by hose into observation ponds instead of being moved with buckets as before.

The experimental design was the same as that used in the Wizard Falls rough-handling test. The mean percentages of delayed mortalities are shown in table 6.

TABLE 5.--Percentages of delayed loss at Wizard Falls in rough loading and unloading experiment, July 26-29, 1954

Tank	55° F.	47° F.
B_1------	0.07	0.10
	0	0
B_2------	.51	.57
	.33	.59
Mean--	.23	.32

TABLE 6.--Percentages of delayed loss at Roaring River in gentle loading and unloading experiment, August 16-19, 1954

Tank	55° F.	47° F.
B_1------	27.51	2.82
	17.56	2.51
B_2------	15.32	8.99
	8.24	6.55
Mean--	17.16	5.22

[3/] Rayner, H. J. Letter to all Oregon State Game Commission fishery field agents and regional supervisors. Portland, Oregon, September 14, 1953.

The data shown in table 6 are not significantly different from those shown for the overhead-spray loads at 47° and 55° F. in table 2. The gentle handling techniques did not decrease mortalities at either temperature and therefore must not be considered effective in reducing delayed losses at the Roaring River hatchery.

Once again the high temperature - high delayed mortality, and low temperature - low delayed mortality, correlation showed up significantly. The repeated appearance of this relationship establishes its validity, especially at the Roaring River hatchery.

Experiment IV
Comparison of Two Types of Venturi Aeration Systems on Delayed Mortality

In Experiment I, venturi aeration proved superior to overhead spray in reducing delayed losses. As the Oregon State Game Commission possessed two distinct types of venturi-aerated tanks, a test was designed to determine the comparative ability of each to reduce delayed mortality.

Temperature, because it did not affect delayed loss of fish transported in venturi-aerated tanks, was eliminated as a factor for consideration in this experiment. The temperature was controlled to 47° F. in all loads, however, to ensure uniform conditions within the tanks.

Load density was selected for testing when preliminary work by D. W. Linn indicated that venturi tanks were capable of carrying satisfactorily more than 3 pounds of fish per 5 gallons of water. For this experiment, the densities of 1.0 and 1.2 pounds of fish per gallon of water were chosen.

To determine the advantages and disadvantages of high and low circulation speed, these factors were varied in this test. The measure of high and low speeds was indicated by the water pressure registered by a gauge mounted on the discharge side of the circulating pump. These pressures were maintained at the desired level by use of a governor controlling engine speed at a constant rate.

The first half of Experiment IV was run at the Leaburg trout hatchery, and the second half of this experiment was run at the Klamath trout hatchery. The mean percentages of delayed mortality suffered at the two stations are shown in table 7.

In tank C, water circulation proceeded from back to front with a relatively gentle current regardless of pump motor speed. Though the average loss was greater at slow circulating speed (pressure reading, 12 pounds per square inch) than at the higher rate (22 pounds per square inch), the difference was not significant. Even though there was no marked increase in turbulence when circulation was rapid in this tank, the dissolved oxygen available--as measured at the beginning and end of the hauls--was approximately 2.0 parts per million greater than at the slower velocity.

In the side-delivery venturi, tank D, the loss pattern was reversed, as the high speed produced a significantly greater number of delayed mortalities than the low speed. Dissolved oxygen content at the start and finish of the hauls varied little between the two speeds, but there was a great deal more turbulence at the higher rate. At low engine speed, the rolling motion of the water might be termed "leisurely." Possibly because there was no definite current in one plane for orientation, the fish appeared nervous and milled about a good deal during transportation. At high speed, the fish were unable to maintain position and were carried around the tank by the forceful movement of the water.

Extremely interesting results regarding load densities were obtained. In the past, it has been assumed that the fewer the fish or the lighter the poundage of fish per gallon of water, the better the survival would be. Such an assumption may be valid in most instances, but in this it was not. Except for the hauls made at low circulation speed in the side-delivery tank, the mean percentage of loss was always higher in the low-density loads. The average delayed loss for all hauls in the experiment was 2.20 percent at a

TABLE 7.--Percentages of delayed loss at Leaburg and Klamath trout hatcheries during tests which evaluated two venturi aeration systems in terms of load density and speed of water circulation, August 23 - September 4, 1954

Tank	Circulation speed	1.0 pound of fish per gallon of water	1.2 pounds of fish per gallon of water	Mean
C---------		(3.85	1.30)	
	Low----------	(4.30	.75)	1.85
		(0	.90)	
	Mean---------	2.72	.98	
		(.20	0)	
	High----------	(1.18	0)	.39
		(.95	0)	
	Mean---------	.78	0	
	Column mean--	1.75	.49	1.12
D---------		(0.57	0.16)	
	Low----------	(.34	1.29)	0.42
		(0	.14)	
	Mean---------	.30	.53	
		(.19	4.90)	
	High----------	(8.82	1.84)	3.94
		(6.01	1.87)	
	Mean---------	5.01	2.87	
	Column mean--	2.66	1.70	2.18
Pooled column mean--------		2.20	1.10	

density of 1.0 pound of fish per gallon of water, and 1.10 percent at a density of 1.2 pounds per gallon. Although this difference is not significant, the data suggest that venturi-aerated tanks may be capable of efficiently transporting fish at a rate in excess of 1.2 pounds per gallon of water.

High rate of water circulation is desirable as long as it is accompanied by an increase in dissolved oxygen and does not create turbulence or agitation at a level that is detrimental to the fish being transported. In the "California" tank, rapid circulation was advantageous; in the side-delivery venturi tank, it was not. A comparison of all the factors tested favors tanks of the "California" design.

Summary

1. A water temperature of 40° F. during transport offered an effective control of delayed mortalities from Roaring River and Wizard Falls trout hatcheries.

2. Sodium amytal at the rate of one-half grain per gallon of water, as used at the Roaring River hatchery, was ineffective as a control of delayed mortalities.

3. Variation of loading and unloading techniques did not significantly affect the delayed losses at either Roaring River or Wizard Falls.

4. Use of venturi-aerated liberating units offered effective control of delayed losses from all four stations.

5. In reducing delayed mortalities at the Leaburg and Klamath trout hatcheries,

the California-type venturi-aeration tank was superior to the side-delivery design described here.

6. Diet, fish condition, water turbulence in liberating tanks, and density of fish per gallon of transporting water may have important bearing on delayed losses. Future work should include exploration of their importance.

Acknowledgments

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Hatchery-produced rainbow trout and wild brown trout are able to survive prolonged periods of starvation. Fifty percent of the rainbow trout and sixty percent of the brown trout starved during a 248-day period (October to June) survived. The surviving brown trout, however, failed to recover from the effects of starvation after being fed diets of natural stream food organisms; whereas the rainbow trout survivors made a 20-percent recovery. Results of the survival and starvation experiments raised questions as to the actual importance of competition between hatchery and wild trout in streams.

PRELIMINARY RESULTS ON THE USE OF POTASSIUM PERMANGANATE TO COUNTERACT THE EFFECTS OF ROTENONE ON FISH

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COMPOUNDS CONTAINING ROTENONE have become widely used in fishery management in the past 20 years (Krumholz 1948, Solman 1949). Present-day fishery biologists use rotenone for many types of problems, including such problems as killing all the fish in a lake or pond, sampling a fish population in a lake or stream, and killing only a part of the fish population in a body of water. In all of these practices, one disadvantage is the length of time required for the toxic effects of the chemicals to dissipate. Normally, in waters having a temperature of 70° F. or higher, one must allow 5 to 7 days to elapse from the time of treatment until it is safe to restock with fish. In sampling a stream population, a kill will be obtained for a considerable distance below the sample area before the concentration is dilute enough to be no longer toxic to fish.

Experiments have been and are continuing to be conducted by the A. P. I. Agricultural Experiment Station to determine whether toxicity of rotenone to fish can be counteracted by addition of some chemical to the water. The results of this work to date are summarized in this report.

As most chemists working with rotenone have observed that the compound is fairly easily oxidized when exposed to air and light (Leonard 1939), one of the first tests on the control of its toxicity was to treat the water with a strong oxidizing agent. One of the cheapest and most active oxidizing agents, yet not toxic to fish at low concentrations, is potassium permanganate. This chemical, at concentrations approaching 2 p.p.m., is used extensively in ponds as a treatment for bacterial and fungal infections of minnows (Prather et al. 1953).

Toxicity of Potassium Permanganate to Pond Fish

The toxicity of potassium permanganate to bluegills, Lepomis macrochirus Rafinesque, largemouth bass, Micropterus salmoides (Lacépède), goldfish, Carassius auratus (Linnaeus), and to fathead minnows, Pimephales promelas Rafinesque, was determined in aquaria at temperatures of 58° and 68° F. The fish were allowed to live in the aquaria for 48 hours prior to the treatment with potassium permanganate. The results of these tests indicated that in aquaria at 68° F., the minimum concentration of potassium permanganate that would kill bluegills was 3 p.p.m.; largemouth bass, 4 p.p.m.; goldfish, 6 p.p.m.; and fathead minnows, 5 p.p.m. At a temperature of 58° F., the minimum concentration of potassium permanganate that was lethal to the bluegills, bass, and fatheads was 5 p.p.m.; and to goldfish, 7 p.p.m.

To determine the length of time that potassium permanganate remained lethal to fish, the dead fish were removed as soon as they died in those aquaria that contained lethal concentrations of the chemical. These aquaria were restocked 24 hours after treatment; and, in all concentrations ranging from 3 to 7 p.p.m., there was 100 percent survival of the three species of fish being tested.

Use of Potassium Permanganate To Make Water Safe for Fish After Rotenone Poisoning

A. Tests in Aquaria. --The first experiments with potassium permanganate and rotenone were conducted in aquaria that contained bluegills, goldfish, fathead minnows, and largemouth bass as test animals. The fish were allowed to live in the aquaria for 48 hours before treatment. Then a concentration of 0.05 p.p.m. rotenone (1 p.p.m. Noxfish, an emulsifiable preparation that contained 5 percent rotenone) was added to the test aquaria. In some of these aquaria a concentration of 2 p.p.m. potassium permanganate was added after the fish became distressed, whereas in other aquaria no treatment with potassium permanganate was applied. In each series of tests control aquaria were maintained, and the survival in all controls was 100 percent. The results of these tests are summarized in table 1.

In another series of experiments in aquaria, bluegills, fathead minnows, and largemouth bass were used as test animals. These fish were allowed to live in the aquaria for 48 hours prior to treatment. One group of aquaria in this series was treated with 0.05 p.p.m. rotenone and 1 p.p.m. potassium permanganate at the same time. The other group was treated with 0.05 p.p.m. rotenone and

TABLE 1.--Summary of experiments in aquaria to counteract toxic effects of rotenone by using potassium permanganate after fish became distressed

Temperature (° F.)	Kind of fish[1/]	Rotenone (p.p.m.)	Time to show distress (minutes)	Potassium permanganate added at first signs of distress (p.p.m.)	Time for recovery (minutes)	Survival after 48 hours (percent)
81	Bluegills-----	0.05	20	2	30	40
	Bluegills-----	.05	20	0	-------	0
	Goldfish------	.05	20	2	30	75
	Goldfish------	.05	20	0	-------	0
68	Fatheads------	.05	23	2	30	100
	Bass----------	.05	30	2	45	100
58	Bluegills-----	.05	40	2	30	100
	Fatheads------	.05	40	2	30	100
44	Bluegills-----	.05	95	2	45	40
	Fatheads------	.05	95	2	45	95
	Bass----------	.05	95	2	60	100

Each group of tests also included two or more control aquaria. The survival in these controls was 100 percent.

[1/] Stocking: (All aquaria, 15-gallon capacity, filled with 40 liters of water)
81° group: 4 aquaria, 10 bluegills each; 4 aquaria, 10 goldfish each.
68° group: 2 aquaria, 10 fatheads each; 2 aquaria, 4 bass each.
58° group: 2 aquaria, 10 bluegills and 10 fatheads each.
44° group: 2 aquaria, 10 bluegills and 10 fatheads each; 2 aquaria, 4 bass each.

2 p.p.m. potassium permanganate at the same time. The results are shown in table 2.

The results of all tests revealed that the toxicity of rotenone to fish could be counteracted by the addition of potassium permanganate to the poisoned waters. In these tests approximately 2 parts of potassium permanganate were needed to detoxify 0.05 part of rotenone.

B. Tests in Ponds.--Early in the winter of 1954, four 1-acre ponds that had been drained were partly refilled with water. They were treated with a concentration of 0.10 p.p.m. rotenone on December 10, 1954. This treatment killed wild fish in these ponds within 24 hours. The water temperature at that time was 42° F. On December 13, 1954, the ponds were treated with potassium permanganate at the rate of 2 pounds of potassium permanganate per 0.05 pound of rotenone. This gave a concentration of 4 p.p.m. potassium permanganate in the pond water. Cages containing fathead minnows were placed in the ponds 24 hours later. None of these minnows died within the following 24-hour period, and the ponds were restocked with fish on December 15, 1954.

A second field test of this technique was tried on four farm ponds that had been drained and had started to refill with water. To prevent the new experiments from being contaminated with fish that might still be living in the ponds, rotenone at a concentration of 0.10 p.p.m. was applied on January 5, 1955. This treatment killed fish stranded in these

TABLE 2.--Summary of experiments in aquaria to counteract toxic effects of rotenone to fish by adding different concentrations of potassium permanganate at the same time rotenone was applied

Temperature (° F.)	Kind of fish[1/]	Added at same time		Additional potassium permanganate		Survival after 48 hours (percent)
		Rotenone (p.p.m.)	Potassium permanganate (p.p.m.)	After approximate time (minutes)	Concentration (p.p.m.)	
81	Bluegills-----	0.05	1	55	1	20
	Bluegills-----	.05	1	60	1	64
	Bluegills-----	.05	2	-------	------	100
	Bluegills-----	.05	2	-------	------	98
	Bass----------	.05	1	55	1	40
	Bass----------	.05	1	70	2	100
	Bass----------	.05	2	-------	------	75
	Bass----------	.05	2	-------	------	75
68	Bluegills-----	.05	2	-------	------	100
	Fatheads------	.05	2	-------	------	100
	Bass----------	.05	2	-------	------	100
58	Bluegills-----	.05	2	-------	------	100
	Fatheads------	.05	2	-------	------	100
44	Bluegills-----	.05	2	-------	------	100
	Fatheads------	.05	2	-------	------	100
	Bass----------	.05	2	-------	------	100

Each group of tests also included one or more control aquaria. The survival in these aquaria was 100 percent.

[1/] Stocking: (All aquaria, 15-gallon capacity, filled with 40 liters of water)
81° group: 20 aquaria, 10 bluegills each; 10 aquaria, 4 bass each.
68° group: 2 aquaria, 10 bluegills and 10 fatheads each; 2 aquaria, 4 bass each.
58° group: 2 aquaria, 10 bluegills and 10 fatheads each.
44° group: 2 aquaria, 10 bluegills and 10 fatheads each; 2 aquaria, 4 bass each.

ponds within 24 hours. The water temperature on that date was 52° F. Twenty-four hours later, cages containing fathead minnows were placed in the ponds to check the rotenone toxicity at this low temperature. Within 12 hours all the minnows were dead. The ponds were next treated with 2 pounds of potassium permanganate for each 0.05 pound of rotenone that had been added. Fathead minnows in cages were placed in the ponds 1 hour after this treatment. A check at the end of 24 hours showed that in two of the ponds all of the minnows were alive, but in the other two ponds all of the minnows were dead. Minnows were again added to these two toxic ponds 48 hours later, and, at the end of another 24-hour test period, all of these minnows were dead. These two ponds then received an application of potassium permanganate at a concentration of 4 p.p.m. on January 12, 1955. The surface water temperature at that time was 40° F. Fathead minnows in cages were again placed in the ponds 24 hours after this second treatment. At the end of a 24-hour test period, there was 25 percent loss of minnows in one pond and 75 percent mortality in the other.

As these ponds were in the process of refilling and were only partly full at the time of treatment, it is believed that the volume of water was overestimated; thus, the concentration of rotenone was in excess of 0.10 p.p.m. If such were the case, the concentration of the potassium permanganate was considerably greater than 4 p.p.m. when the first test cages containing fathead minnows were added. Thus, it appears probable that the fatheads were killed by the potassium permanganate rather than by the rotenone. The later treatments with potassium permanganate would have aggravated this condition and continued to kill the test fish.

To study further the problems that were encountered in the ponds that have just been described, twelve 0.25-acre ponds were poisoned with a 0.05-p.p.m. concentration of rotenone on April 25, 1955. This treatment killed wild fish within 2 hours. To neutralize the toxicity of this rotenone, potassium permanganate at a concentration of 2 p.p.m. was applied 24 hours later as a water solution. A test cage containing 10 fathead minnows was placed in each pond 24 hours after the potassium permanganate treatment. These cages were checked daily for mortality of fatheads; there were no deaths within the next 11 days. The surface water temperature during the period ranged from 71° to 82° F.

Another series of six 0.25-acre ponds was poisoned with rotenone at the rate of approximately 0.05 p.p.m. on April 26, 1955, and the results were the same as those described in the preceding paragraph. These ponds were treated with a 2-p.p.m. concentration of potassium permanganate 24 hours later. On these six ponds the potassium permanganate was applied by broadcasting the crystals over the pond surface. Two cages containing two bluegills each were placed in each pond 24 hours after the potassium permanganate treatment. One cage was put in the surface waters, and the other cage was placed 5 feet deep. Within the next 24 hours, the mortality in these cages ranged from 50 to 100 percent, except in two ponds where there were no deaths in the cages at 5 feet.

Another group of eight 0.25-acre ponds was treated with 0.05 p.p.m. rotenone on June 1, 1955. Twenty-four hours later these ponds received a treatment with a 2-p.p.m. concentration of potassium permanganate as a water solution. On the following day two cages containing 10 fathead minnows were placed in each pond. One cage was put in the surface water, and the other cage was placed 5 feet deep. When checked 24 hours later, there was one dead fish in one of the surface cages and one dead fish in one of the cages at 5 feet.

These field tests showed that 2 parts of potassium permanganate detoxified 0.05 part of rotenone in pond waters, and that this concentration of potassium permanganate was not lethal to bluegills or fathead minnows 24 hours after application. The tests also indicated that the application of potassium permanganate as a water solution was more effective in detoxifying

the rotenone than an application of potassium permanganate in crystalline form.

Use of Potassium Permanganate in Rotenone-Sampling of Streams

A further test of the effectiveness of potassium permanganate in counteracting the toxicity of rotenone was conducted by Dr. J. S. Dendy and his fishery class during the fall of 1954 in Uchee Creek, Russell County, Alabama. For several years Dendy and his classes have used rotenone to sample fish populations in small streams near Auburn. In these studies a seine has always been placed across the stream on the downstream edge of the sample area. This seine prevented movement of fish into and from the poisoned area on the downstream side and gave some idea of the kill to be expected from the drift of the poison with the current. Those fish killed below the seine were recorded separately. The kills that were obtained in the sample area and in the stream below are shown in table 3.

During the fall of 1954, Dendy used the same techniques of sampling the streams as in previous years. In addition, burlap bags containing potassium permanganate were dragged back and forth across the stream just below the downstream seine throughout the period the fish were dying in the sample area. The pounds of fish killed by the various methods are compared in table 3.

It is evident that in these three tests the potassium permanganate was very efficient in counteracting the lethal effects of rotenone on the downstream side of the seine. A very interesting event occurred at Station 3 in Uchee Creek. During the sampling operation, a fisherman some 100 yards below the seine was catching fish. The water in the area was then a dark purple, owing to potassium permanganate.

TABLE 3.--Total number of pounds of fish collected by using rotenone with and without potassium permanganate

Year	Location	Total number of pounds of fish collected		Chemicals used	
		In sample area	Below sample area	Rotenone in sample area (p.p.m.)	Potassium permanganate below sample area (pounds)
1952	Sougahatchee Creek:				
	Station 3----------	3.73	3.38	0.1	0
	Station 6----------	3.33	.56	.1	0
	Station 7----------	5.84	4.32	.1	0
	Loblockee Creek:				
	Station 5----------	2.84	3.29	.1	0
1953	Little Uchee Creek:				
	Station 1----------	0.93	0.45	0.1	0
	Station 1A---------	.09	.38	.1	0
	Station 2----------	1.30	.35	.1	0
	Station 3----------	.28	.21	.1	0
	Station 4----------	.95	6.63	.1	0
	Station 5----------	6.20	41.20	.1	0
1954	Uchee Creek:				
	Station 1----------	5.34	0	0.1	6.0
	Station 2----------	17.70	0	.1	15.0
	Station 3----------	7.30	0	.1	15.0

Use of Potassium Permanganate To Reduce Kill of Largemouth Bass After Partial Poisoning of Ponds With Rotenone

Considerable numbers of largemouth bass are often killed in the course of poisoning the edges of farm fishponds to reduce the populations of small and intermediate-sized bluegills (Swingle, Prather, and Lawrence, 1953). The struggling of the bluegills may attract these bass into the poisoned area, or they may move into the area in the evening or after nightfall to feed. As the concentration of rotenone in the edge of a partially poisoned pond exceeds 0.05 p.p.m., many of the bass that come into the edge may be killed even some hours after the rotenone has been applied.

The application of potassium permanganate to counteract the toxicity of rotenone to fish after partial poisoning was tried on several larger ponds operated by the station. The rotenone was applied in a double line around the ponds and allowed to kill small and intermediate-sized bluegills, usually for 1.5 to 2 hours. The edges of the ponds were then treated with potassium permanganate by dragging burlap bags containing the chemical behind motorboats. The amount of rotenone used for partial poisoning of each pond and the amount of potassium permanganate used to detoxify the rotenone are noted in table 4. Also shown in table 4 are the numbers of bass killed in these ponds by partial poisoning with and without treatments of potassium permanganate.

TABLE 4.--Numbers of largemouth bass killed by partial poisoning of ponds by using rotenone with and without potassium permanganate

Pond area (acres)	Rotenone used (pounds)	Potassium permanganate added (pounds)	Large bass killed (number)
26	5.6	100	7
26	2.0	0	38
12	2.0	0	29
22	3.2	0	53
26	2.4	100	14

Use of Potassium Permanganate To Confine Fish-Kill to Area When Sampling Fish Populations With Rotenone

It is often desired to sample the standing crop of fish in a body of water by poisoning a selected area with rotenone and then collecting the dead fish. When such operations are attempted, difficulties with movement of the rotenone outside the sample area are often encountered. Such movement will kill fish that were outside the selected area, thus giving erroneous results.

In an attempt to reduce as much as possible this kill of fish outside a pond area selected for sampling, the following field techniques were tried. On August 9, 1955, a 1-acre sample area of a 22-acre pond was marked and poisoned with a 0.05-p.p.m. concentration of rotenone. Concurrent with the application of rotenone, potassium permanganate at a concentration of 2 p.p.m. was applied a few feet to the outside of the sample-area boundaries by towing bags containing the chemical behind a motorboat. On the following day, another 1-acre sample area in this pond was selected and treated in the manner just described. A 1-acre sample area in a 26-acre pond was also treated in the same manner on this second date.

The field observations on the effectiveness of this potassium permanganate block were very favorable. In all three areas the number of fish in distress outside the poisoned area was negligible, estimated to be less than 2 percent of the total number killed. The second-day pickup was also small, indicating that the poisoned waters did not move as a block into an untreated area and kill large numbers of fish. Also, there were very few bass to be picked up on the second day, contrary to the situation when potassium permanganate was not used.

Summary and Conclusions

It is evident that potassium permanganate is capable of counteracting the toxicity of rotenone to fish and/or oxidizing

rotenone to a nontoxic form. Where tap water was used in aquaria, the toxicity of 0.05 p.p.m. rotenone was effectively counteracted by means of 2 p.p.m. potassium permanganate over a temperature range from 44° to 81° F.

In field trials on ponds and streams, concentrations of potassium permanganate ranging from 2.0 to 2.5 p.p.m. successfully neutralized the toxicity of a 0.05-p.p.m. concentration of rotenone.

In aquaria at a temperature of 81° F., the minimum concentration of potassium permanganate that killed bluegills was 3 p.p.m.; largemouth bass, 4 p.p.m.; and fathead minnows, 5 p.p.m. At a temperature of 58° F., the minimum concentration of potassium permanganate that killed bluegills and largemouth bass was approximately 5 p.p.m.

The use of potassium permanganate apparently had no harmful effects on the waters treated; rather, it is probable that, owing to its fungicidal action, this chemical may have beneficial effects on any fish present or that are added immediately to such treated waters.

Further research on all phases of this detoxifying technique is needed. There is need for more information concerning the concentrations of rotenone and potassium permanganate that are toxic to various fish, as well as the proportional amounts of potassium permanganate required to neutralize completely the rotenone in waters containing different concentrations of salts and organic matter. The appropriate concentrations and method of applying the potassium permanganate to the poisoned area are virtually untouched fields of research.

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A man is known by the company he keeps--and the origin of a salmon taken on the high seas may yet be known by the parasites it supports. Adults and smolts from rivers used for spawning are being collected, examined, and compared with adults from the oceans in an effort to find organisms that are unique to certain river systems, parasitize young salmon, and can be identified in adult salmon.

If the average catch equals one catchable-size fish per hour, the fish manager doesn't worry too much about a particular water. If the catch exceeds that, he sleeps well; if it falls below for long, he may lose some hair, or even his job. -- Willis King.

HISTOPATHOLOGY OF FISH
II. THE SALMON-POISONING FLUKE

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THE SALMON-POISONING FLUKE is misnamed as far as the fish culturist is concerned, for the disease affects dogs, not fish. There is considerable evidence, however, that fish may also suffer from the complex chain of events leading from snail to dying dog. Histological studies indicate that young salmon and trout may be severely damaged by the encysted stage of the fluke.

Bennington (1951) has reviewed the literature of the salmon-poisoning fluke, Troglotrema salmincola (Chapin),[1/] and completely described the life history of this interesting organism. Many animals may be infected by the fluke in laboratory experiments, but it is not known which animals are responsible for transmitting the organism in nature. The adult fluke lives in the intestine of a mammal, and the eggs pass out with the feces. Note that an infestation with flukes is not analogous to an infection with salmon-poisoning disease. Many animals harbor the flukes, but, as will be shown, only the canines are affected by the disease and the resulting mortality.

If the eggs reach water, they eventually hatch and the miracidia emerge. These miracidia must find and penetrate a specific snail, Oxytrema silicula (Lea), if development is to continue. Inside the snail they become rediae, which, in turn, produce many small cercariae. The cercariae are shed from the snail on tiny ropes of mucus which probably help these larvae to become attached to fish. The cercariae cannot swim, so their contact with fish is entirely a chance occurrence. Once that contact is made, however, results are immediate. Sinitsin (1930) was the first to describe actual penetration of fish by the cercariae. Bennington (1951) described the penetration as taking place within 2 minutes and sometimes in 30 seconds. He observed organisms penetrating tails and fins so rapidly that they would sometimes perforate the material and crawl out on the opposite surface. Many of his experimental fish died from the results of this infestation. Shortly after penetration the cercariae form a cyst in the tissues of the fish and then are known as metacercariae. If the fish is eaten by a suitable host, the metacercariae develop into adult flukes in the host's intestine and the cycle is ready to be repeated.

Often, canines that have eaten infected fish sicken within a short time and die. The disease was first described in 1855 (Suckley 1860: 112), and investigators implicated the salmon fluke by about 1911 (Pernot 1911). It was thought originally, however, that the metacercariae, themselves, were responsible for the disease. It was not until 40 years later that the true organism was discovered. Cordy and Gorham (1950) demonstrated that the disease of dogs was actually caused by a rickettsial body that is transmitted by the fluke.

[1/] Also known as Nanophyetus salmincola (Chapin).

It is somewhat surprising that fishery workers have not investigated the inimical effects of the salmon fluke on salmon. When an infected fingerling is examined, the metacercariae are grossly visible as tiny refractile dots on the surface of infected organs. The posterior portion of the kidney generally shows the heaviest infestation. Donham, Simms, and Miller (1926) estimated that an ounce of kidney contained more than a million cysts. Bennington (1951) suggested that during low water in streams heavily infested with Oxytrema the fluke might be quite pathogenic to young fish. Pratt reported at the December 1954 meeting of the Western Society of Naturalists that he was able to kill a 30-millimeter salmon or trout by exposing it to about 3,000 cercariae in a liter of water, and a 50-millimeter salmon by exposing it to about 4,000 cercariae in a liter of water.[2/] It is possibly significant that the metacercariae have not been reported in ocean-caught salmon or in stream-caught salmon which have recently returned from the ocean. As several hatcheries on the Pacific coast release young salmon heavily infested with the parasite, there is a possibility that these fish are not surviving to adulthood.

To investigate the possible tissue damage caused by the metacercariae, a group of yearling silver salmon were selected from a hatchery population infected with the organism. The tissues were fixed in Bouin's solution; and sections were cut from the eyes, brain, gills, heart, muscle, kidney, liver, gall bladder, air bladder, spleen, intestine, and tongue. Four sections were cut from the kidney and seven from the intestine to ensure a complete examination of both organs.

All the tissues examined were infected with metacercariae except the brains, air bladders, and spleens. Usually, there was no intense cellular reaction to the parasite and the tissue elements were merely pushed aside to make room for the metacercariae. In many instances, however, a fibrous wall--several layers thick--was formed around the cyst. Occasionally there was a hyperplasia of epithelial cells to form a pronounced nodule with the parasite in the center. These hyperplastic masses were seen most frequently in the gills, where considerable areas of respiratory tissue were destroyed (figure 1). There was never, however, any invasion of leucocytes to combat the foreign body represented by the metacercariae. It appeared that the organism could generally be considered as a benign parasite, of little consequence as far as tissue reaction and inflammation were concerned. It is of interest to note, however, that hyperplasia and overgrowth of specialized tissues often have been attributed to the larval forms of other helminths (Hegner et al. 1938). It is entirely possible that, in severe infestations, the neoplastic condition observed in the gills would be conducive to gill disease from other pathogenic organisms.

The absence of tissue reaction does not absolve the salmon-poisoning fluke as a potential pathogenic organism of serious consequence to fish. The sections that were observed in this study represented an infinitesimal part of the total tissue volume of the fish. It was apparent that the aggregate of the metacercariae numbered in the thousands. Although little tissue reaction was observed, there was frequent evidence of marked obstructive and mechanical injury. Of the greatest significance, possibly, were the large numbers of organisms observed in the heart. Muscle fibers of the ventricle were often disrupted and deformed (figure 2). The aorta was occasionally the site of a solid wall of encysted organisms (figure 3). There is no experimental evidence to demonstrate that these encysted organisms are capable of causing damage to the heart. The maximum size of the metacercariae in these sections, however, was approximately 0.25 millimeter in diameter. This is approximately one-fourteenth of the greatest diameter of the heart in fish of this size and fully large enough to block the entire aorta. It would

[2/] Personal communication from Dr. Ivan Pratt, Department of Zoology, Oregon State College, Corvallis, Oregon, April 1955.

FIGURE:

1.--Metacercariae and epithelial hyperplasia in the gill. Hematoxylin and eosin. x 100.

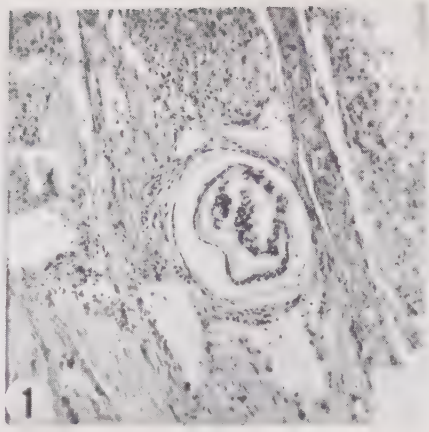
2.--Metacercariae in the ventricle of the heart. Hematoxylin and eosin. x 100.

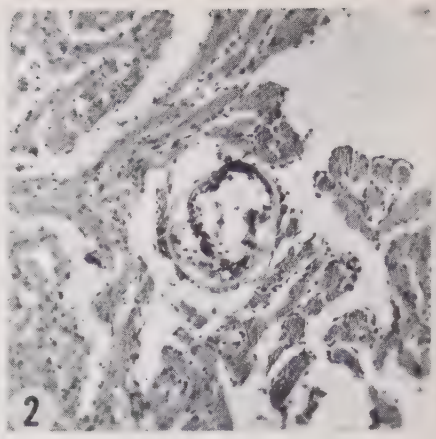
3.--Metacercariae lining the aorta. Hematoxylin and eosin. x 60.

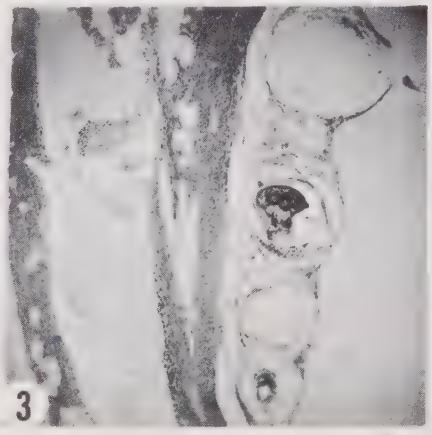
4.--Metacercariae in the retina. Hematoxylin and eosin. x 100.

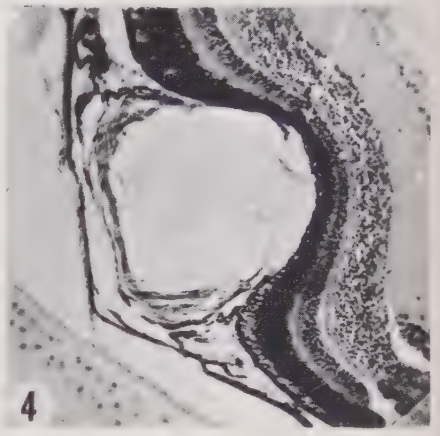
5.--Metacercariae in the posterior kidney. Hematoxylin and eosin. x 60.

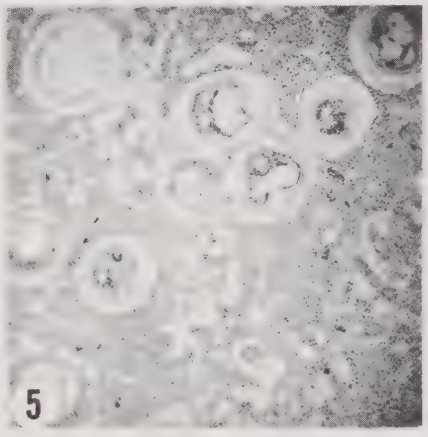
6.--Metacercariae in the posterior kidney. Hematoxylin and eosin. x 100.

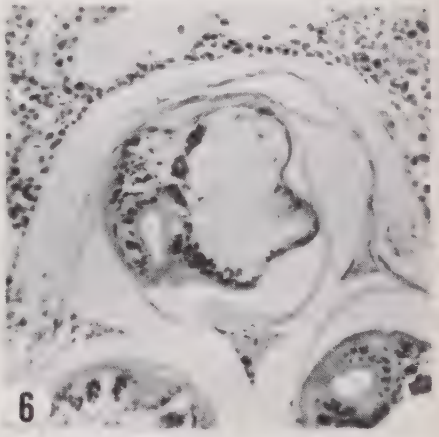












appear that a heart with a large concentration of organisms of such size would be severely handicapped. Other organs were equally affected. The retina of the eye was displaced from its normal curvature (figure 4). Tubules of the kidney were crowded and forced to one side (figures 5 and 6). Organisms in the wall of the gall bladder completely changed the pattern of this organ. Pancreatic tissue was displaced to make room for the cysts.

The salmon-poisoning fluke has often been implicated with kidney disease. Both Earp (Earp et al. 1953) and Snieszko and Griffin (1955) have suggested a relationship between the rickettsia of the disease in dogs and kidney disease in fish, though this viewpoint appears less likely at present. 3/

3/ Personal communication from Dr. S. F. Snieszko, U. S. Fish and Wildlife Service, Microbiological Laboratory, Leetown Station, Kearneysville, West Virginia, 1955.

Nevertheless, kidney disease is frequently seen in hatcheries with a heavy infestation of Nanophyetus. Hegner and his cowriters (1938) discussed the wounding action of penetrating cercariae of blood flukes and stated that secondary bacterial infections often arise. Although the wound itself may not be important, a serious, superimposed infection by pathogenic bacteria may result. In view of the difficulties in experimental transmission of kidney disease by feeding infective material (Snieszko and Griffin 1955), this potential pathway of infection is of considerable concern.

The entire picture of the salmon fingerling infected with Nanophyetus is one of a fish that is physiologically weakened in practically every organ. This study was not intended to provide conclusive proof that the parasite is inimical, but there are ample indications that a definite attempt should be made to determine whether hatchery fish infected with the salmon-poisoning fluke are capable of withstanding the stress and rigors inherent in survival to adulthood.

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The collection of larval sailfish as small as 3.6 millimeters in length indicates that Gulf Stream waters along the southern Atlantic coast of the United States are important spawning areas of the sailfish, and that spawning of this species takes place from April through September.

SIZE DISCRIMINATION IN THE BROOK, BROWN, AND RAINBOW TROUT

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FOR MANY YEARS, AQUATIC BIOLOGISTS AND LAYMEN ALIKE have noted behavioral differences between brook, brown, and rainbow trout. However, experimental studies designed to determine the basic mechanisms which may contribute to or produce these variations have been sadly lacking. Therefore, conclusions pertaining to interspecies behavioral differences seem to be based upon anecdotal evidence for the most part.

Some theorists believe that we may obtain species comparisons by determining the fish's ability to learn a sensory discrimination, i.e., to learn to perform a specified response to one stimulus and to inhibit a response to another similar stimulus. Reeves (1919), for example, demonstrated rudimentary color discrimination in fish by a modification of the discrimination learning paradigm. The present authors also hold that the ability of fishes to learn a sensory discrimination offers an adequate criterion by which behavioral differences may be studied. By the use of such methodologies it should then be possible to determine the relative psychological position of different species of fish.

The purpose of the present study was to compare brook, brown, and rainbow trout in their ability to learn a size discrimination. In addition, the effect of learning one size discrimination upon the learning of a subsequent finer discrimination was determined for the three species.

Subjects

Group I consisted of 8 brook trout, group II of 8 rainbow trout, and group III of 8 brown trout. The mean length of the fish in all groups was 7.5 inches. All the trout had lived under almost identical conditions throughout their lives; all had been reared and hatched at Wolf Lake Hatchery, Mattawan, Michigan. This site also was utilized as the experimental site.

Apparatus

The apparatus used was a screen box 16 inches long, 9 inches wide, and 11 inches deep. The front of the box was constructed of brown fiberboard, in which were cut windows 5 inches high and 3 inches wide. These windows were placed 1 inch from the bottom and sides of the box and 1 inch apart. Latches (not visible from the interior of the box) were fixed above each window, on the exterior of the box. When they were down, the clear plate-glass slides containing the discrimination stimuli remained firmly in place; and when up, they could be readily pushed out by the fish. The discrimination box was suspended in a large aquarium with an independent water supply. The original water source and temperature were

Psychological Research Services, Inc., is under contract to the Michigan Department of Conservation.

identical for both the experimental and the holding aquaria.

Procedure

Subjects (trout) were placed in the box for 5 trials with no slides in the windows. If a subject did not escape within the first 10 seconds, he was given noxious stimulation by mechanical means, i.e., tapping lightly on the tail with a short stick. Subjects were then given 5 additional avoidance trials with both slides placed in the windows. For these trials the stimuli were not placed on the slides and both latches were left open. In this manner subjects were habituated to pushing aside the glass slides to avoid noxious stimulation.

On the following day the discrimination trials began. The stimuli for the first discrimination series were painted on the slides, which were then inserted in the windows. The larger stimulus was a circle 0.75 inch in diameter, while the other was a circle 0.50 inch in diameter. Both circular stimuli were painted a flat brown, the same as the front of the apparatus. Subjects were put into the discrimination box from a separate holding tank by use of a regular scap net. The only escape channel was through the window having the smaller stimulus, as the latch for the window with the larger stimulus was always down. If the subject did not make a choice within the first 10 seconds after being placed in the box, he was given additional noxious stimulation until he made a choice. However, this procedure was utilized only in the early stages of learning. If a subject made a wrong choice, he was allowed to recoil from the negative stimulus and make the correct choice afterwards. To preclude the establishment of a position preference, the stimuli were alternated so that the smaller stimulus was in the following position for each of the 10 daily trials: left, right; left, right, right; left, right, left, left, right. Ten spaced (10 minutes' intertrial interval) trials were given daily until the criterion of 10 successive correct discriminations was reached. The pressing of a nose against the wrong window was considered a wrong response. Thus, each subject had to swim directly to the window with the smaller stimulus 10 successive times before learning was considered complete.

On the day after the acquisition of the first discrimination habit, the learning of the second discrimination was begun. The stimuli for these trials were of the same shape and color as in the preceding trials. The diameters of these stimuli, however, were 0.50 inch and 0.25 inch. In this connection, it should be pointed out that the stimulus which was positive in the first discrimination has now become the larger stimulus and therefore negative. In all tests, escape could be effected only by pushing over the window containing the smaller stimulus. The identical procedure and criterion which were utilized in the first part of the present study were utilized for this second discrimination.

None of the subjects was fed throughout the course of the present experiment. A recent study by Adelman, Bingham, and Maatch (1955) has shown that in 45° water fish of the utilized size range can remain longer than 7 months under a condition of complete deprivation of food without showing appreciable mortality. As the present water temperature fluctuated around 45°, the authors felt that feeding might produce some sluggishness that would interfere with subsequent learning. It was also for precisely this reason that the present discriminations were learned under avoidance conditions rather than approach conditions. As the metabolic processes of the fish have slowed in 45° water, one or two pellets would be sufficient to produce satiation. However, the present design calls for 10 trials per day, which could be accomplished only through utilization of instrumental avoidance - conditioning technique.

Results

The results of the learning to discriminate between stimuli of 0.75-inch and 0.50-inch diameters are presented in table 1. As can be seen, the brown trout

reached the criterion in 18 trials, whereas the rainbow and brook trout took an average of 29.5 and 32.8 trials, respectively. The difference between the brook and brown trout was significant beyond the 0.001 level of confidence, whereas the remaining comparisons did not reveal any significance. Thus, for the first discrimination problem, it would seem that brown trout can resolve stimulus differences more readily than either of the other two species.

The results of the learning to discriminate between stimuli of 0.50-inch and 0.25-inch diameters are presented in table 2. The brown trout again averaged 18 trials to reach the learning criterion, whereas the rainbow and brook trout took 16.6 and 50.3 trials, respectively. The differences between the brown and brook trout were significant beyond the 0.01 level of confidence, and the difference between the rainbow and brook trout was significant beyond the 0.001 level. It is therefore apparent that both rainbow and brown trout were able to make sensory discriminations more readily than the brook trout.

The attempt to determine the effect of learning one discrimination upon the speed of learning a second presents widely disparate results. The brook trout showed a significant increase in number of trials to learn the second discrimination ($t = 2.80$), the rainbow trout revealed a significant decrease ($t = 2.40$), and the brown trout exhibited no change. Therefore, the amount of transfer from one situation to another would seem to be more a function of the species in question than the operation of a systematic variable for trout in general.

Discussion

The results seem to support the common observations that brown and rainbow trout are more "intelligent" than brook trout. More important, however, is the fact that learning to make a sensory discrimination offers a methodology for interspecies comparison. Such procedures could ultimately permit the establishment of a behavioral scale similar to the phylogenetic scale utilized in biological fields.

Differences among the species in the ability to make a size discrimination lend additional support to the hypothesis that brook trout are the most easily caught of the trout species. If it is difficult for brook trout to resolve size differences, it would seem to follow that they would more readily attack a wider variety of terminal tackle. Thus, inability to distinguish between floating food and lines would possibly lead to an increased susceptibility to the angler's hook.

Differences among these three fishes with regard to sensory discrimination of size by no means presents the complete

TABLE 1.--Results of the learning to discriminate between stimuli of 0.75-inch and 0.5-inch diameters

Species	Mean trials	t-Value
Brook trout------- and Brown trout-------	32.82) 18.00)	5.83
Brook trout------- and Rainbow trout-----	32.82) 29.50)	0.57
Brown trout------- and Rainbow trout-----	18.00) 29.50)	1.91

TABLE 2.--Results of the learning to discriminate between stimuli of 0.50-inch and 0.25-inch diameters

Species	Mean trials	t-Value
Brook trout------- and Brown trout-------	50.30) 18.00)	4.90
Brook trout------- and Rainbow trout-----	50.30) 16.60)	2.40
Brown trout------- and Rainbow trout-----	18.00) 16.60)	1.21

mechanisms underlying more complex behavior differences. Ability to make other discriminations may significantly interact with the size variable to produce the behavior so commonly observed. For this reason the present authors are now experimenting with shape, movement, and olfactory discrimination by utilization of similar methods. The complete results of this experimentation should present a clear picture of some of the variables that operate to produce overt, identifiable behavior.

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MARKERS FOR BRUSH SHELTERS

Brush shelters in Gavins Point Reservoir, a newly created 30,000-acre impoundment on the Missouri River in South Dakota and Nebraska, are being marked with drums that contain blocks of styrofoam. Described by James T. Shields of the South Dakota Department of Game, Fish and Parks, these markers are expected to serve as guides for fishermen over a long period of time.

To provide cover for the fish, and to provide areas likely to attract large numbers of fish, 9 brush shelters have been located on the South Dakota side of the impoundment and 12 on the Nebraska side. Approximately 50 feet by 100 feet by 8 feet high, these shelters--100 to 150 yards apart--are set in groups of 3, and these groups are at least 1,000 yards apart. All shelters are anchored by 3/8-inch galvanized cable to large stumps remaining in the ground.

As 4 to 10 feet of water will cover the tops of the shelters when the reservoir is at operating level, it has been considered necessary to mark the shelters in order to assist sport fishermen in taking an increased harvest from these points of concentration.

Fisheries biologist for large impoundments in the South Dakota organization, Mr. Shields writes:

"To mark these brush shelters permanently, 15-gallon grease drums will be attached to the shelters with 3/8-inch galvanized cable. Sealed in the drums are blocks of styrofoam, the plastic substance that is placed under the seats of some aluminum boats to keep them afloat in the event that they are upset. Thus, should vandals or indiscriminate target-shooters put holes in the drums, they will remain afloat indefinitely, or until they can be replaced.

"Seven blocks of styrofoam--each block measuring 2-1/2 by 12 by 4 inches--have been used in each drum. This is enough to float about 30 pounds, or slightly more than the combined weight of the drum and cable.

"The retail cost of the styrofoam was less than $3 for the amount used in each drum."

In 1955, control structures on Lake Michigan took 46,268 sea lampreys.

THE INLAND FISHERIES OF INDONESIA

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THE INLAND WATERS OF INDONESIA include some 7 million hectares[1/] which may be considered as 2 separate groups, those which are under cultivation and those which remain in their natural state. The waters under cultivation include the brackish-water ponds as well as the fresh-water ponds, the ricefields, and the reservoirs; the waters under natural production include the marshes, lakes, rivers, and similar bodies of water. The total production of all inland waters was estimated at 241,000 long tons in 1953. This low production per unit resulted from the low rate of capture in the natural waters, which--though they cover not less than 6 million hectares--are little exploited because of the difficulties of harvesting (being in unpopulated areas) and because many of the large areas are insufficiently stocked. These figures, however, show the great possibilities for increasing the yield from the inland waters.

Culture in Brackish-Water Ponds (Tambaks)

In certain coastal areas having extensive tidal flats, fish farming is practiced in ponds which are filled with sea water at high tide but which can be drained at low tide. The salinity of these ponds varies with the amount of rainfall and river water available. The sea water reaches the ponds by means of extensive rivers or canals, some of which are many kilometers long; only a few of these ponds receive their water directly from the sea.

The ponds are constructed by building embankments with sluice gates. The bottoms of the ponds must be on a level a little higher than low tide so that they can be drained completely. The ponds are stocked with Chanos chanos (known as bandeng in Indonesia), a fish resembling a herring. The bandeng is a sea fish that spawns twice each year, at the changes of the east and west monsoons. As bandeng do not spawn in captivity, the fry must be caught along the beaches of the inland seas. In some regions bandeng fry appear only once a year, from April to August. During a rearing period of 6 to 12 months in the ponds, the fish grows to marketable size, when it weighs from 200 to 1,000 grams. In deep ponds bandeng may be reared for longer than a year and reach a weight of 3 kilograms or more. Besides bandeng, the tambaks produce prawns and other fishes which enter the ponds with the tidal water. The brackish-water ponds in Indonesia have a total area of 120,000 hectares and yield some 31,000 tons of fish per year. Along the coasts of the many islands there are thousands of hectares of unreclaimed tidal forests which may be used for Chanos culture. The possibilities for increasing the acreage and yield of the tambak fishery, too, are very great.

Culture in Fresh-Water Ponds

Most of the ponds getting their water from rivers and irrigation canals are naturally rich in fish food; the streams which pass through villages, forests, and

[1/] A hectare is approximately 2.5 acres.

A typical hatchery on Java. The Inland Fishery Service runs about 1 hundred such hatcheries (averaging 1 hectare of pond area), and there are more than 1 thousand privately owned hatcheries. The total annual production of these hatcheries exceeds 13 billion fry and fingerlings.

A ricefield being prepared for fish culture by ditching and then strengthening the dike. Some 50 thousand hectares of land are now being used for this combination of rice and fish culture on the islands of Java, Sumatra, and Sulawesi.

(Illustrations courtesy of the author)

ricefields carry along many nutrients from which fish foods are built. Some of the ponds, however, receiving water from wells and springs, are poor in nutrients. These ponds will give a good yield only if artificial food is provided.

There are about 17,000 hectares of fresh-water fish ponds, yielding about 18,000 tons of fish per year. Gradually the pond areas are increasing, especially in the islands outside Java. The per-unit production of the fresh-water ponds is four times that of the brackish-water ponds because of the better location of the former in relation to the sources of many kinds of waste and sewage from home industries of foodstuffs, from barns, villages, and towns. From such sources the ponds receive gratis many kinds of manure. For the brackish-water ponds, however, this situation occurs only where a tambak is near a big city--as are only a few of the tambak sites. Most ponds lie in areas where waste and sewage are unavailable. In these ponds green manure is used; this is expensive and available only in limited quantities, with the result that production is low. The Inland Fisheries Service is seeking a source of cheap manure which could be obtained in adequate quantities in the neighborhood of the tambak sites.

Culture of Carp in Ricefields (Sawahs)

Many fields are used for the production of fish as well as rice. In areas with sufficient water, the ricefields are flooded to a height of 15 to 20 centimeters directly after the rice has been harvested and the straw cut off. The fields are then stocked with 2 to 4 thousand 5- to 8-centimeter fingerlings per hectare. These develop, in 3 to 4 months, into marketable fish of about 50 grams.

In order to raise marketable fish in such a short period, it is necessary to start with fairly large fingerlings--5 to 10 centimeters in length--rather than with the fry, which are but 0.5 to 1 centimeter long. In areas having sufficient water to permit successive plantings of rice, a resting period of 4 or 5 weeks is allowed between the harvest of one crop and the planting of the next. During this resting period the fields are flooded for use as rearing ponds. Up to 50 thousand carp fry per hectare are introduced into such fields. During the resting period these fry develop to a length of 2 to 3 centimeters and the mortalities range from 30 to 50 percent. When this sawah is to be planted with rice, the small fingerlings are transplanted in an adjacent field that is entering its resting period; there, in the 4 to 5 weeks allowed, these fingerlings attain a length of 3 to 5 centimeters. In turn, they are moved to a third field, where they attain a size of 8 to 10 centimeters. At this time they are ready for transfer to a recently planted field, where they will have the 3- to 4-month rice-growing season in which to mature to marketable size.

Culture of Tilapia in Combination With Rice Cultivation

A week after rice planting, the sawah is flooded to a height of 5 centimeters and stocked with mudjair (Tilapia mossambica) fingerlings, 4 to 5 centimeters in length, at the rate of 1 thousand per hectare. Gradually the water level is increased to a height of 15 to 20 centimeters, depending on the growth of the rice. With the ripening of the rice, i.e., in 3 to 4 months after planting, the fish are harvested. The yield, 40 to 50 kilograms per hectare, consists of fry as well as marketable fish.

In other cases, a month or two after rice planting, when the first weed-control work is done, the sawah is stocked with fry or fingerlings of the common carp (Cyprinus carpio). The water level and the number stocked are the same as those described in the foregoing paragraphs.

If the ricefields are used for fish culture, dikes must be bigger and stronger than would be necessary for rice alone. The required soil is taken from the sawah bottom along the dikes, providing a ditch along the margin of the sawah. In the combination of fish and rice culture, a ditch through the middle of the field must be provided. The in- and out-flowing

water is regulated by means of bamboo pipes, and bamboo screens are provided to keep the fish from escaping. These ditches are necessary not only as hiding-places for the fish, but also as collecting-places in which to harvest the catch.

Fish Culture in Irrigation Reservoirs

Two types of reservoirs--small and large--are distinguished. Small reservoirs, 0.25 to 1 hectare in expanse and about 0.5 to 0.75 meter in depth, are exploited as ponds by use of the techniques already outlined. Large reservoirs, comprising tens of hectares and depths of several meters, are considered as marshes and are less intensively cultivated than the small reservoirs.

In flooded sawah areas along some of the big rivers of Java, if the water is less than 1 meter deep, fish ponds are built by constructing higher dikes. These ponds last 4 to 6 months before drying out, this depending on rainfall. They are stocked with bandeng fry and with fingerlings of the cyprinid Puntius javanicus. In the beginning of the dry season the fields are planted with rice. When the water is run off, holes remain under water and contain several kinds of fish. These holes are considered temporary ponds. The fish production, however, is low.

Fish Capture in Surface Waters

Marshes or swamps.--A marsh has the following features: the surface of water is very variable, depending on the monsoon; the water is only a few meters deep, with great differences in depth occurring between the wet and dry seasons; the shallow parts are mostly overgrown with grasses, shrubs, and water plants.

There are two groups of marshes: (1) Those in which the water supply is sufficient during the whole year, and (2) those in which, during the dry season, the water supply is insufficient.

To increase the fish production, the following measures are usually taken:

a. Fishing is prohibited in and around the junctions of the rivers with the marshes during the spawning season of certain species, especially the two cyprinids, Puntius javanicus and Osteochilus hasselti.

b. Harmful methods of capture, such as dynamiting or poisoning, are prohibited.

c. Mesh sizes are restricted in order to protect small fish.

d. The capture of predators and nonedible species is encouraged, not only because a predator requires no less than 5 kilograms of flesh from other types of fish for each kilogram of its own weight, but also because these predator fish compete with the marketable fish for food.

e. The waters are stocked with fish that do not occur in the marshes but which are of economic value and will not harm the valuable indigenous fish.

f. Sumps are constructed on the lower parts, where the fish may gather in the marshes when the water supply decreases. It is also desirable to maintain the existing sumps.

Lakes.--Lakes are commonly deep and have clean water that is poor in fish food. Nevertheless, lakes can be used for fish culture if capture is possible and transport to markets is available. Stocking with new fish is desirable, provided that sufficient natural fish foods are available.

Rivers.--The rivers in Java are commonly short of fish. This is not true, however, in a few large rivers which are directly connected with the sea and give access to the sea fish, or in the rivers which have big, deep marshes where the fish may seek refuge during the dry season. The shortage of fish in those rivers is caused, in particular, by harmful catching methods and lack of water during the dry season.

In the islands other than Java, especially in Borneo and Sumatra, the rivers have an adequate supply of water throughout the year. Many of the rivers--which are hundreds of kilometers long--pass through virgin forests, seldom visited by man. It is not surprising that these rivers have large fish populations. In contrast to

the situation in Java, the large rivers in the other islands are hiding-places for fish from the marshes during the dry season. A great part of these fish, however, are caught before they reach the rivers.

A new method of fish culture is now being practiced in rivers within or near big towns. The fishes are reared in bamboo baskets measuring 2 meters long, 1 meter wide, and 0.75 meter deep. The basket is put into the river at a depth of 0.5 to 0.6 meter.

The basket is stocked with 300 common carp fingerlings, 5 to 8 centimeters in length. Gradually the stocking number is decreased according to the increased uses of the fish.

One basket produces in 7 to 8 months some 100 carp, each weighing 300 to 500 grams, depending on the fertility of the water. The water of the rivers in and near big towns is very rich in fish food, especially for the common carp. Artificial feeding is, therefore, not necessary. This fish culture is expanding gradually.

FIELD TRIAL OF ELECTRIC SHOCKERS

In recent years many types of electrofishing devices have appeared. Although there are many papers describing these devices, fishery workers generally have little information as to the most suitable types to employ for specific purposes. Almost every State now uses a different type of electric shocker. Many organizations are still seeking to improve their electrofishing methods but lack facilities and time necessary to develop the best shocker design.

In the spring of 1954, biologists from Florida, Kentucky, Tennessee, Virginia, West Virginia, and the U. S. Fish and Wildlife Service held a 2-day field trial in Tennessee to determine the relative merits of individual shockers and methods. The conferees compared the performances of 6 different electric shockers under similar conditions.

The shockers were operated on an arm of a reservoir and on a small stream. The water in the impoundment was clear and 3 to 20 feet deep. The water in the stream (average width, about 35 feet; maximum depth, about 5 feet) was clear to slightly turbid from recent rains. The total hardness of the waters concerned was about 100 p.p.m. calcium carbonate equivalent, and the resistance of these waters was 10 to 12 thousand ohms per cubic centimeter.

All the units demonstrated could easily be transported by small boat; two, weighing less than 50 pounds, were battery-powered and portable by back-pack. One unit employed direct current; the others used alternating current. Two shockers were constructed to provide a deeper field (front to rear) to prevent escape of fish; a third shocker was designed on the principle of two separate electrodes, each T-shaped to deepen the field. Still another unit made use of an alternate-polarity system. Two of the designs operated during the conference were equipped with a push-button switch for control of the field, and one also had a test light built into the switch brail to indicate current flow as far as the electrodes.

One of the battery-powered shockers used a 6-volt motorcycle battery and was of the type described in 1954 by Haskell in New York. The shocker powered by a 6-volt auto battery was of comparatively simple construction, consisting of merely the battery, vibrator, transformer, rheostat, and electrodes.

At the conclusion of the demonstrations the conferees agreed that each type of electrical shocker had shown certain advantages--some types more than others--but that not one could be recommended as meeting all of the requirements for a shocker without some modification.

THE COMPARATIVE RETURNS OF VARIOUS SIZES OF TROUT STOCKED IN MASSACHUSETTS STREAMS

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EXCEPT FOR THE EARLY FINGERLING VERSUS LEGAL-SIZE HATCHERY TROUT STUDIES, which conclusively revealed the economy of stocking the latter instead of the former in a put-and-take fishery, the literature offers only limited and indirect reference to the possibilities of differential return, from streams, of legal-size hatchery trout stocked according to size. Miller (1952) noted a significant difference in the survival of two similarly treated lots of hatchery trout that differed only in size and age. One-third of 199 3-year-olds ranging from 12 to 15 inches in fork length and all, or nearly all, of 201 2-year-old hatchery-reared trout ranging from 5 to 8 inches in fork length died shortly after planting--as measured by dead fish recovered from the experimental area. Other investigators engaged in hatchery-trout studies have generally noted only the average size range of trout stocked and sorted recoveries only as to species and time of stocking.

Procedure

Substantial numbers of trout were tagged, beginning in 1952 and continuing to date, in connection with the Dingell-Johnson stream-investigational project. Primary objectives revolved about assessing harvest, differentiating between wild and hatchery trout, and a host of other factors that did not include the possibilities of differences in returns according to the size of the fish stocked. Efforts were directed toward tagging a more or less randomized portion of the total allotment of trout scheduled for the drainage under study and marking the remainder by fin-clipping. Trout were tagged with circular monel-metal jaw tags attached to the mandible. Various sizes of tags were used on the various sizes of fish. An anesthetic solution of 0.5 percent urethane was used to immobilize all trout temporarily before tagging.

Massachusetts' trout-cultural operations have long included use of an arbitrary method of grading trout. Yearling trout up to 8 inches in total length are referred to as 6-8's, fast-growing yearlings or slow-growing 2-year-olds between 8 and 9 inches are referred to as 8-9's, and 2-year-olds between 9 and 12 inches are referred to as 9-12's. The older discarded brood stock is designated as 12 inches plus. Such a grading procedure allowed for tagging by size-range lots. Individual length measurements were made on all or representative numbers of fish of each lot. Different sizes of fish were remixed prior to shipment or in the stream.

Findings

Percentage of returns (tag recoveries in hand) by stocking sizes, for 62,680

This work was undertaken with Federal Aid in Fish Restoration funds, as part of Dingell-Johnson Projects, F-1-R-1, 2, and 3, Massachusetts.

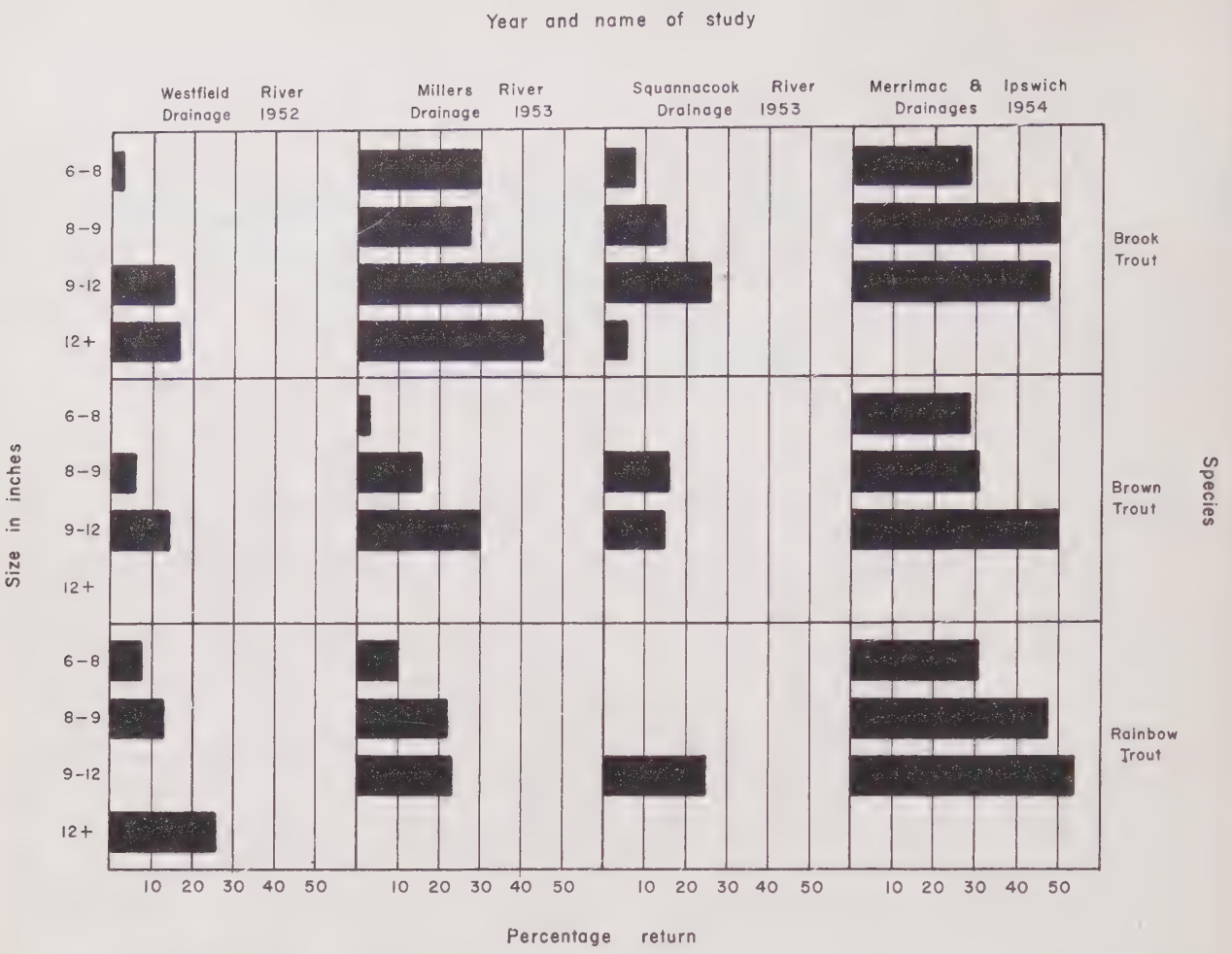

FIGURE 1.--Percentage of returns, by stocking sizes, of 62,680 tagged trout stocked in 5 major Massachusetts stream drainages in the month of March.

tagged brook, brown, and rainbow trout stocked in 5 typical, major stream drainages during the month of March over the last 3 years, shows a significantly greater return for the larger fish as compared to the smaller fish planted (figure 1, table 1). Yearling 6- to 8-inch fish gave the poorest return, 9- to 12-inch 2-year-olds gave the highest return, 8- to 9-inch yearlings or 2-year-olds gave returns between these aforementioned categories, and 12-inch-plus brood stock provided returns comparable to those of 9- to 12-inch fish. Valid comparison requires the deletion of the last category, as it represents discarded brood stock; they represent the frosting of the annual total hatchery output and cannot be produced economically for stocking purposes even though much in demand by the angler.

Attention is focused on the fact that all these recoveries represent actual tags recovered. No corrections for tag nonrespondence are included in the data presented. Marked differences in the tag-recovery levels between drainages are attributed to the use of tag-return boxes (which greatly facilitated sportsmen's cooperation in returning tags) on the Millers, Ipswich, and Merrimac drainages, and to inherent differences in runoff, angling pressure, watersheds, and year studied between drainage systems. Therefore, valid comparison is possible only between

TABLE 1.--Number of tagged trout stocked in March and (in parentheses) percentage of actual tag-in-hand recoveries according to average size range

Name and year of study	Brook trout				Brown trout			Rainbow trout			
	6 - 8 inches	8 - 9 inches	9 - 12 inches	12+ inches	6 - 8 inches	8 - 9 inches	9 - 12 inches	6 - 8 inches	8 - 9 inches	9 - 12 inches	12+ inches
Westfield River drainage, 1952---	970	------	1,484	383	------	1,772	3,920	2,967	------	1,543	94
	(3)	------	(15)	(17)	------	(6)	(14)	(8)	------	(13)	(26)
Millers River drainage, 1953---	6,138	1,584	4,950	298	1,188	990	2,970	1,980	198	2,475	------
	(30)	(28)	(40)	(45)	(3)	(16)	(30)	(10)	(32)	(33)	------
Squannacook River drainage, 1953---	1,683	792	2,400	50	------	1,584	990	------	------	495	------
	(8)	(15)	(26)	(6)	------	(16)	(15)	------	------	(25)	------
Merrimac and Ipswich River drainages, 1954----------	4,752	1,485	1,881	------	990	1,386	4,950	891	1,286	990	------
	(29)	(50)	(48)	------	(29)	(31)	(50)	(31)	(48)	(54)	------
Total or average--------	13,543	3,861	10,715	731	2,178	5,732	12,830	5,838	1,484	5,503	94
	(25)	(34)	(35)	(28)	(15)	(17)	(32)	(14)	(45)	(31)	(26)

species and size in a particular drainage and not between drainages, even though the premise of differential recovery due to size is apparent (figure 1, table 1).

Although minor discrepancies exist, the average increment of return between 6- to 8-inch trout and trout more than 8 inches in length approximates 50 percent (21 percent actual return for 6- to 8-inch trout, 31 percent for trout above this size).

Limited corollary information for in-season stockings and recoveries by size groups agrees with that presented but is not reported on at this time.

Possible Explanations

It is possible that the apparent differential in return according to stocking sizes is accounted for by the fact that anglers returned tags to a greater degree from the larger trout than from the smaller trout. Though it is pretty well accepted that angler interest is stimulated more by large trout than by small ones, it is doubtful whether a difference of an inch or two would promote the significance of return noted, especially on drainages where field contact and tag-return boxes were used.

A more plausible explanation of the results is that the larger trout, owing to greater body size, were better able to cope with stream velocities and competition, thereby surviving longer and being vulnerable to angling over a longer time. This agrees substantially with Miller's (1952, 1954) trout survival studies.

Management Significance

During the year 1954, slightly less than 1 million legal-size trout (6 inches plus) were distributed to public fishing waters. Approximately one-half million of these were in the 6- to 8-inch class and averaged less than 7 inches in total length. These were planted in streams on a put-and-take basis. By cutting the numerical stocking rates by one-third and stocking a similar poundage of 8-inch-plus fish, the same numbers of trout could be harvested by the angler, but the creel weight would be increased by 33 percent. This is predicated in terms of yearlings only and would necessitate artificial inducement of early spawning by light manipulation and the holding of the groups of smaller fish for in-season stocking at larger sizes. These procedures would reduce the mortalities produced by stocking smaller trout during that period of high water which normally precedes the trout season in Massachusetts.

Acknowledgment

Sincere appreciation is expressed to William A. Tompkins, chief aquatic biologist, and all other Division personnel for assistance and encouragement in compiling and presenting these data.

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During 1955, 11 States--Connecticut, Delaware, Florida, Maryland, Massachusetts, New Jersey, New York, North Carolina, Rhode Island, South Carolina, and Virginia--cooperated in a program for the study of the striped bass. Research demonstrated that races of the striped bass exist in the Hudson River, Chesapeake Bay, Santee-Cooper River, and the St. Johns River. Above Pinopolis Dam in the Santee-Cooper region of South Carolina, a "land-locked" race was studied.

REPORT ON THE AIR-JET FISH-DEFLECTOR TESTS

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THE POLICY OF THE CALIFORNIA DEPARTMENT OF FISH AND GAME is to develop and test new types of fish screens in an effort to find an efficient device, easily produced and installed, which could be adapted to any size of water diversion. A nonmechanical screen has been particularly sought after to reduce maintenance costs.

Various methods of directing, deflecting, or repelling fish have been tested. Electric screens, moving lights, and sonic gear have not proved satisfactory in saving young seaward-migrant salmon and steelhead. The louver screen was found to deflect fish satisfactorily, but trash accumulated rapidly on this structure and caused serious loss of head.

During the studies on fish preservation at a Contra Costa steam plant in 1952, it was found that in a test flume small fish of several species could be deflected with a curtain of air bubbles. As this discovery had no application to the fish-salvage problem at the Contra Costa plant, no further experiments were conducted.

The possibilities of the air-bubble screen were brought to the attention of Ernest Murphey of the Elk Grove Screen and Ladder Shop. Murphey constructed, during the fall of 1954, an air-jet fish deflector which made use of both bubbles and a noise-making contrivance. This equipment consisted of a 21-foot piece of 2-inch pipe that was drilled and tapped at 12-inch intervals to receive 1/2-inch shutoff cocks. One end of the pipe was plugged, and a fitting was installed on the other end for connection to an air supply.

Attached to the shutoff cocks, at right angles to the 2-inch pipe, were 3-foot pieces of 1/2-inch pipe. The length of these pipes could be altered according to the depth of the stream or canal where installation was to be made. On either end of each 1/2-inch pipe, a bell reducer (2 inches to 1/2 inch) was mounted. Each reducer was equipped with a circular diaphragm of 22-gauge stainless steel. An adjustable tension device held the diaphragm in position and permitted variation in the frequency of the sound.

The sound and air-bubble equipment was installed at the mouth of the South Stanford Vina Canal on Deer Creek, in Tehama County, for testing. The 2-inch pipe was placed in position slightly above the water surface, running from one bank to the other. The row of 1/2-inch pipes extended almost to the bottom of the stream and perpendicular to the flow.

In operation, an air compressor was connected to the 2-inch pipe. The air supply escaped through the reducers, causing the diaphragm to vibrate and produce a continuous blast of sound. At the same time the water was agitated by the ascending wall of air bubbles. To the observer it appeared that the combined effect of noise and bubbles would frighten away any fish in the vicinity.

On April 18, 1955, before the air jets were put in operation, 3 fyke nets were placed in the canal to determine the number of salmon moving down the unscreened ditch. The 3 nets, side by side, strained most of the 60 cubic feet per second flowing in the canal. A total of 166 salmon were captured during the night's fishing.

TABLE 1.--Salmon length frequencies during air-jet tests at South Stanford Vina Canal in three periods

Length (mm.)	Frequency taken April 18-19	Frequency taken April 19-20	Frequency taken April 20-21
36	1	9	-------
7	4	4	5
8	2	8	5
9	4	3	11
40	4	6	11
1	3	2	3
2	1	------	3
3	------	1	2
4	------	1	1
45	1	3	1
6	1	1	1
7	2	2	2
8	------	1	2
9	------	3	1
50	1	3	-------
1	------	1	-------
2	1	------	-------
3	1	------	-------
4	2	------	-------
55	1	------	1
6	1	1	1
7	3	------	-------
8	1	------	-------
9	1	------	-------
60	------	4	-------
1	------	1	-------
2	2	------	-------
3	1	------	-------
4	1	1	-------
65	2	------	-------
6	------	1	-------
7	3	------	-------
8	1	------	-------
9	1	------	-------
70	------	1	-------
1	------	1	-------
2	------	------	-------
3	------	1	-------
4	------	------	-------
75	1	------	-------
6	------	1	-------
7	1	------	-------
80	1	------	-------
81	1	------	-------
83	1	------	-------
93	1	------	-------
100	1	------	-------
106	1	------	-------
113	1	------	-------
Total measured--	55	60	50
Average length----	56.64	45.83	41.28
Not measured--	111	220	2,108

On April 19, the air-jet deflector was placed in operation and netting in the canal was continued. To check the efficiency of the screen, 407 small salmon were seined from Deer Creek upstream from the water diversion and marked by clipping the dorsal lobe of the caudal fin. These fish were returned to Deer Creek, near the point of capture, on the afternoon of April 19. The following morning 280 salmon, including 16 marked fish, were taken in the nets in the canal. Thus, with the air-jet deflector in operation, the numbers of fish lost in the canal actually showed an increase over the preceding night's catch.

On the afternoon of April 20, seining in Deer Creek produced 205 young salmon. These fish were marked by removing a portion of the ventral lobe of the caudal fin. Again the release was made at the point of capture upstream from the South Stanford Vina Canal. The following day, though the air jets had been operating continually, 2,158 salmon were removed from the fyke nets. Of these salmon, 11 were marked fish from the release of April 19, and 29 were from the release of April 20. All these fish had ignored the screen.

The sharp increase in the fyke-net catches after the air-jet device was in operation was undoubtedly caused by a rise in the flow of Deer Creek, which hastened the downstream movement of the small salmon. However, from the numbers of fish captured and the presence of marked fish in the catch, it was obvious that the air-jets were accomplishing little in the way of deflecting salmon.

It is, of course, impossible to state exactly why the air bubbles failed to repel fish on Deer Creek. The most obvious explanation is that the fish were accustomed to turbulent water because of the numerous riffles and rapids in the stream. As far as the noise-making properties of the air-jet deflector are concerned, it is recognized that, though a sudden sharp noise or vibration may frighten fish temporarily, they soon become accustomed to a continuous vibration.

An interesting fact was discovered during analysis of the data from the screen tests. This fact was the marked decrease in the average length of the fish during the 3 nights of fyke-netting. As may be seen from the accompanying length-frequency table (table 1), the average length dropped from 56.64 millimeters on the first night to 45.83 millimeters on the second, and to 41.28 millimeters on the third. A random sample of at least 50 fish was measured on each occasion.

The air-jet device was retired after more than 48 hours' continuous operation. It was obvious that further experiments with this equipment were not justified.

POPULATION CHANGES AND STUDIES CAUSED BY THE SEA LAMPREY

The establishment of the sea lamprey in the Great Lakes has resulted in marked changes among fish populations. These changes have clearly demonstrated the need for control of the sea lamprey and for measures designed to restore or replace populations of desirable species.

Intensive study of fish populations in the open, deep waters of Lake Michigan during 1955 confirmed suspicions that lake trout are almost nonexistent there. Thus, only 8 lake trout were captured in more than 1,000 miles of gill net spread at various depths throughout the lake. Under average conditions prior to the invasion and establishment of the sea lamprey, 1,000 miles of netting set in these waters would have captured more than 57,000 lake trout.

This study of the extent of survival of the lake trout revealed changes in other populations in the Great Lakes. Since the disappearance of the lake trout population, the bloater--a small cisco that was once the major food of the lake trout--has increased its numbers by about 300 percent. However, the numbers of a larger species of cisco, or chub, have declined about 27 percent, and lamprey depredation--as well as a heavy commercial fishery--may reduce still further the number of these desirable fish.

To reestablish the lake trout fishery in Lakes Huron and Michigan, it will be necessary to stock these waters with artificially produced lake trout after control of the sea lamprey has been achieved. Three years ago, when it was obvious that lake trout populations would require assistance if they were to recover from the inroads of the sea lamprey, fishery workers undertook a project to develop the most efficient and successful methods of handling and planting hatchery-produced lake trout. One phase of this project involved a study to determine the influence of planting time upon the success or failure of stocked fish: in this study, paired lots of marked yearling lake trout were planted--one of the pairs in the fall and the other the following spring--in Lake Superior. The preliminary returns from these lake trout have favored overwhelmingly the practice of stocking during the spring. The optimum depths of water for planting the hatchery trout have been learned rather definitely by studies of the distribution of natural lake trout of the same sizes as the hatchery fish planted in Lake Superior. Further investigations are being conducted to determine just how much growth in the hatchery will be necessary to ensure good survival of the planted lake trout.

A DRAG-TYPE RIFFLE-BOTTOM SAMPLER

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IN THE COURSE OF WORK performed for the California State Water Pollution Control Board in 1953 and 1954, it became necessary to develop a new type of stream-bottom sampler. As this piece of apparatus may be of interest to limnologists and others concerned with stream-bottom sampling, it seems desirable to publish a description of it at this time.

The most serious objection to such sampling devices as those reported by Needham (1928), Surber (1937), Wilding (1940), and Hess (1941), is that their use is restricted to water of depths less than an arm's length. The drag-type sampler (figure 1) was therefore designed to take samples from riffles at any depth. The new sampler is similar in principle to certain marine dredges, but it is much smaller and is adapted in various ways to stream conditions. It was devised in consultation with Dr. G. Dallas Hanna and was made in the instrument shop of the California Academy of Sciences.

Description of the Sampler

The drag-type sampler consists of a rectangular iron box, which operates on either side, with bars on the open face to exclude large rocks and trash. The tines, which dig into the rock and gravel of the bottom, serve the same purpose as the fingers of operators of the shallow-water-type samplers. The current sweeps the organisms into a net, just as in those samplers.

The net bag is removable and can be opened by means of a zipper to take out organisms. The net bag may be made of any strong material. In our tests nylon net or 24-mesh silk bolting cloth was used. Mesh of the latter size is about as fine as can be safely used. The net must permit a good flow of water and at the same time retain minute organisms such as midge larvae and pupae, simuliids, or others. A canvas sleeve is provided to protect the net. Care should be taken at all times to see that the protective skirt covers the net.

Discussion

The new sampler, like others referred to here, will not work in still or very slowly moving water. Sampling can be done from the middle of a riffle, from a prominence on shore, or even from a bridge above a stream. Difficulty was encountered in sampling from high bridges, but this may be overcome by adjusting weights on the sampler and weighting the line several feet in front of the sampler.

Several difficulties have arisen in using the new sampler. One disadvantage is that it will not take satisfactory samples in mud or sand and will not work on bed rock. Another disadvantage is that the net, although protected by a canvas sleeve, tears easily under the rough treatment to which it is inevitably subjected. Sand grains tend to interfere with the action of the zipper, and for this reason it must be rinsed thoroughly after each use. Care must be taken to avoid catching the net with the zipper. In large streams it is not possible to wade very far from the shore because of the depth and swiftness of the water. The only alternative is to take the samples in suitable shallow riffle areas

where bottom materials are small enough to permit the tines of the sampler to penetrate and stir up the stones as it is pulled upstream. Obviously, the drag-type sampler--or any sampler, for that matter--cannot be used in stream bottoms where large boulders compose the substrate. The term "large" here refers to stones or boulders larger than a football. Still larger boulders can often be used as platforms from which to pull the sampler.

The type of riffle bottom in which the drag-type sampler works most efficiently is composed of stones smaller than grapefruit with coarse and fine gravel filling the interspaces. In preliminary tests it has been found that the drag-type sampler, when pulled over 10 feet of bottom, takes organisms in numbers and proportions roughly similar to those taken by the square-foot Surber Sampler.

Sampling Technique

The operator drops the sampler into the current, open end upstream, holding it by the bridle and attached rope. If the current is sufficiently swift, it will aid the operator by carrying the sampler downstream in preparation for pulling it the required distance. If the sampling is performed from a bridge and the current is swift, the sampler may not settle properly on the bottom. In this event, the extra weights provided should be fastened to the sampler.

The sampler should always be pulled parallel to and against the direction of flow. Samples cannot be taken with the drag-type sampler crosswise of the current or at right angles to the direction of flow. When the pull is completed, the sampler is lifted from the water with the bridle and placed on some solid object in preparation for removal of the materials collected. The zipper is then opened, the net is turned inside out, and the contents are dumped into a bucket. The resulting sample contains the usual sand, gravel, leaves, and fine stones. The inverted net end is swirled in the solution to dislodge

(Drawing courtesy of the authors)

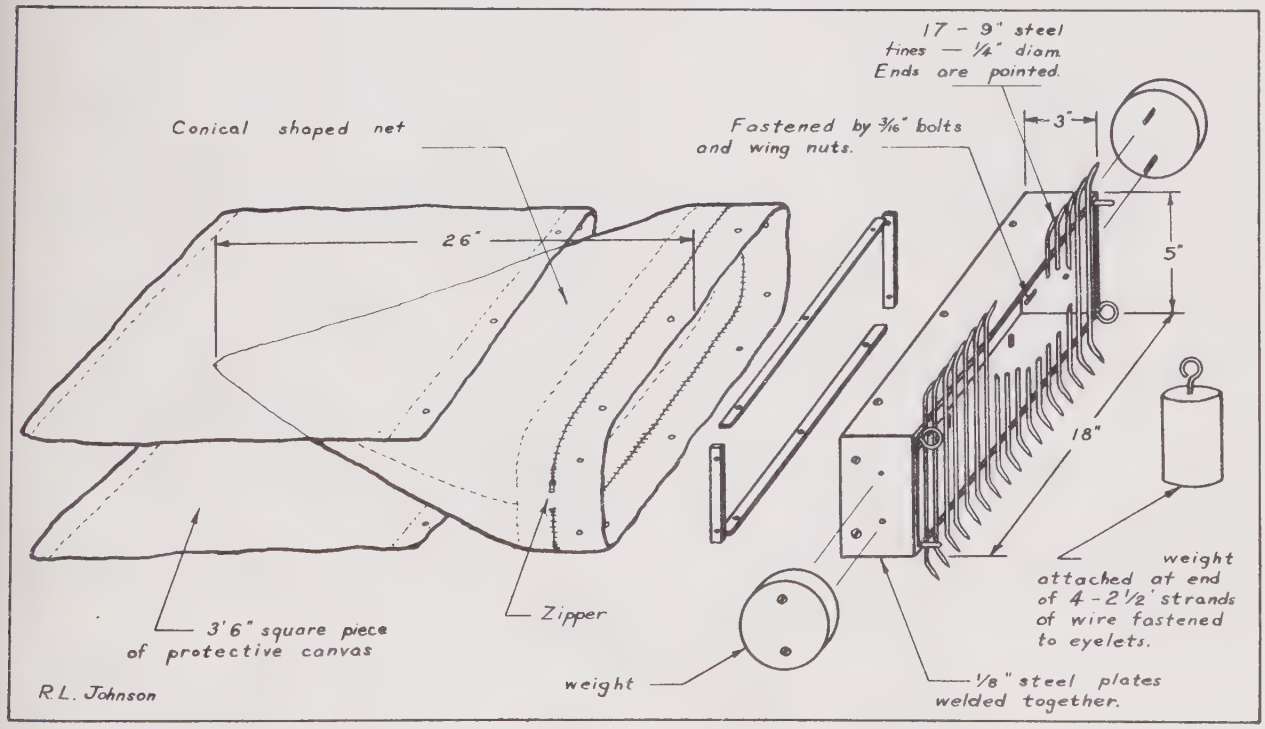
17 - 9" steel tines — ¼" diam. Ends are pointed.
Conical shaped net
Fastened by 3/16" bolts and wing nuts.
3"
26"
5"
18"
weight attached at end of 4 - 2½' strands of wire fastened to eyelets.
3'6" square piece of protective canvas
Zipper
weight
⅛" steel plates welded together.
R.L. Johnson

FIGURE 1.--Details of the drag-type sampler.

clinging organisms. The larger trash and stones are removed by hand after washing thoroughly to dislodge attached organisms.

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FEED HEAVY ON A RISE IN TEMPERATURE

The body temperature of fishes and other poikilotherms approximates the temperature of their environment. Because metabolic activity varies with temperature, feeding charts call for more food for fish that are held in warmer waters. However, in hatcheries that have variable water temperatures, fish culturists have learned that it is desirable to feed well above the chart values when the water temperature is rising and somewhat below those values when it is dropping.

Experimentally it has been demonstrated that, for many poikilotherms, those previously accustomed to a lower temperature will have a higher metabolic rate--temporarily, at least--than those accustomed to a higher temperature, when they are tested at the same temperature. Also, it has been shown that a brown trout, if placed in water 10 Centigrade degrees higher than that to which the fish was acclimated, will promptly exhibit an oxygen consumption as much as 70 percent higher than the normal for the higher level. In about a day, the metabolic rate will drop to the rate that is normal for the higher temperature. The fish will not overshoot to the same extent in making the change to a new metabolic level as a result of a comparable decrease in temperature.

Such limited experimental data help to confirm and explain the maxim noted by practical fish culturists: Feed heavy on a rise in temperature.

Pertinent research may be reviewed in two papers which were published in the August 1955 issue (volume 30, number 3) of Biological Reviews of the Cambridge Philosophical Society. The papers are: "Physiological Variation in Animals" by C. Ladd Prosser (pages 229 to 262) and "Compensation for Temperature in the Metabolism and Activity of Poikilotherms" by Theodore Holmes Bullock (pages 311 to 342).

In 1955, research vessels took steelhead trout 1,300 miles from shore.

GROWTH OF THE SMALLMOUTH BUFFALO IN CARP PONDS

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SMALLMOUTH BUFFALO AND CARP were planted in two central Missouri farm ponds. Rather surprisingly, the buffalo made gains in weight and the carp lost.

Although the buffalo is of little value as an angling species, the fish is receiving an increasing amount of attention as a satisfactory food fish that is easily and cheaply reared in a variety of situations. Investigation of the rearing of buffalo in farm ponds in the United States has lagged because of the want of interest in raising other than game species. The evidence presented here, however, suggests that buffalo culture in ponds might be profitable and deserves more investigation.

Pond 1, a fertilized pond having 0.47 acre of surface area, was stocked with smallmouth buffalo and carp during the period October 20-25, 1952; and the fish population was removed during the period October 10-24, 1953. These species were planted in pond 3, an unfertilized pond with 0.25 acre of surface area, on October 10, 1953; and the fish population was removed on July 5, 1954.

When stocked with smallmouth buffalo and carp, pond 1 contained 4 flathead catfish and an established population of largemouth bass and bluegill. When the fish population was recovered, the 11 largest bass averaged 3.0 pounds each and the 4 catfish averaged 4.1 pounds. The presence of 500 to 600 bluegill is of interest because they may compete with buffalo for food. Pond 3 had small populations of bass and pumpkinseed prior to stocking. Two months before removal of the fish populations, 6 bass and 40 bluegill were added.

Recovery of the fish from the ponds by seining and by poisoning with rotenone was facilitated by (1) the absence of filamentous algae and higher aquatic plants, (2) the small size of the ponds, and (3) the shallowness of the ponds (maximum depth for pond 1, 5 feet; for pond 3, 2.5 feet). The buffalo and carp remaining in pond 1 after seining on October 10 and October 21 were all recovered, as far as is known, within 3 hours of the application of the poison on October 24. The buffalo and carp in pond 3 were all recovered within 2 hours of the application of the poison, except for 1 carp which was recovered the next morning. Checks made for a week after the poisoning revealed no additional carp or buffalo in either pond.

Owing to the long period of dry weather, the surface area of these ponds shrank steadily. Pond 1 lost 19 percent of its area (shrinking to 0.38 acre) and pond 3 lost 32 percent (shrinking to 0.17 acre) during the period that the fish were in each.

Table 1 summarizes the information on numbers and weights of fish in the ponds.

In both ponds the buffalo made significant gains in weight while the carp lost. During the 12 months in pond 1, the buffalo made a weight gain of at least 250 percent and the carp lost 10 percent. During 9 months in pond 3, the buffalo gained 18

Contribution from the Missouri Cooperative Wildlife Research Unit; the U. S. Fish and Wildlife Service, Wildlife Management Institute, Missouri Conservation Commission, Edward K. Love Foundation, and University of Missouri cooperating.

TABLE 1.--The number, average weight, and pounds per acre of fish planted and recovered

(Based on pond surface area at start of experiment)

Species	Number		Average weight (pounds)		Pounds per acre	
	Planted	Recovered	Planted	Recovered	Planted	Recovered
Pond 1						
Buffalo	15-20	9	1/ 0.50	4.67	1/ 25.5	89.6
Carp	320	223	0.91	1.17	617.0	557.4
Game fish 2/		26		2.10		115.9
Total						762.9
Pond 3						
Buffalo	3	3	3.77	4.43	45.2	53.2
Carp	183	182	1.26	1.11	924.0	806.8
Game fish		55		0.24		53.6
Total						913.6

1/ Or less.
2/ Only the larger bass and bluegill and the 4 catfish are included for pond 1.

percent in weight and the carp lost 13 percent. The gains that were made by the fish in pond 3 were not representative of a year's growth, as the fish were removed during the middle of the growing season.

With regard to the loss of number of carp in pond 1, it should be noted that many of the fish planted were 3 to 6 inches long. The significant reduction in number of carp (97) may have been due to predation by the large bass and catfish present. This loss of small carp would result in a population of greater average weight, with only a small loss in total weight.

All of the carp and buffalo planted in pond 3, however, were more than 8 inches long, a size large enough virtually to insure against predation by fish-eating birds or by the few bass present. This safety in size is reflected in the survival of almost 100 percent of these carp and buffalo in the 9 months between planting and recovery.

After the planting of the carp in these ponds, the waters showed considerable increase in turbidity due to silt and clay in suspension. The water in pond 1 maintained an average Secchi-disc reading of about 12 inches, whereas water in pond 3 had an average reading of about 3 inches. With these high turbidities, especially for pond 3, it is rather surprising that the ponds maintained as large a fish population as they did.

The results of this limited experiment would suggest that in a mixed population of buffalo and carp, the buffalo--because they alone increased in weight--may be either more efficient in food utilization or able to utilize food items that the carp cannot. Whether this growth advantage would persist for different ratios of carp and buffalo, or for unmixed populations, remains to be determined. Whatever the cause of the difference, further investigation should prove of value, especially should we be faced in the future with the necessity for producing greater quantities of animal protein more cheaply than we do now.

A section of goldfish heart tissue has been kept alive outside the fish 181 days.

OXYGEN EQUIPMENT FOR FISH TRANSPORTATION

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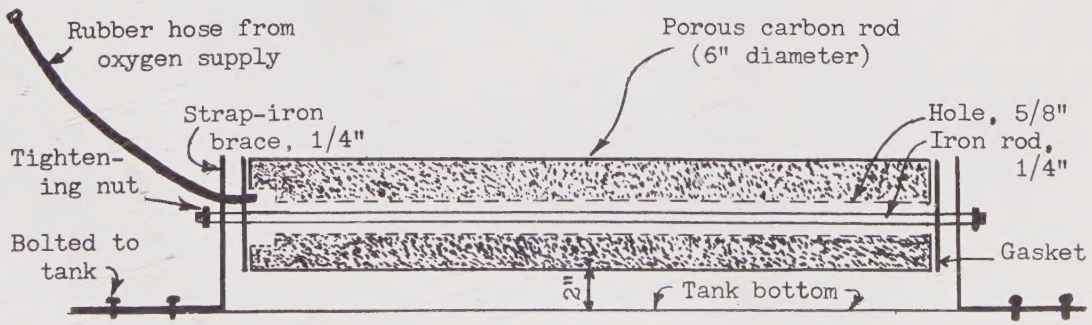
THE FISH DIVISION of the Wyoming Game and Fish Department has equipped all of its fish-distribution trucks with the oxygen-supply equipment described here. Aeration previously was effected by means of pumps equipped with venturi valves and a system of water circulation. That system had many disadvantages, however, including failure of the pumps, clogging of intakes, and lack of means for varying the oxygen content of the water on long trips. The system described here is based on ordinary welding-type oxygen equipment which permits variation in the pressure as needed and has proved itself most beneficial throughout an entire season's use. This system is simple to install, operate, and maintain; and its cost is quite minor, especially in view of the increased survival of fish during hauling.

In a distribution tank 6 feet long, 4 feet wide, and 4 feet high, a single carbon rod, 4 feet long and 6 inches in diameter, is used. Lengthwise through the center of the carbon rod, a hole 5/8 inch in diameter has been drilled; and at one end of the rod, a hole 1-1/2 inches in diameter and 2 inches deep has been drilled. A 1/4-inch steel rod is run through the hole in the center of the carbon rod and bolted to a strap-iron brace, 1/4 inch thick and 1 inch wide, at each end. These braces are bolted securely to the bottom of the distribution tank. As shown in the drawing, the braces are set so that the carbon rod is held at least 2 inches above the bottom of the tank. The steel rod is threaded so that the nuts on either end will draw the upright part of the brace against a gasket placed between the brace and each end of the carbon rod, thus making the installation air tight. A rubber tube with threaded metal connections conducts the oxygen from the supply to the carbon rod, entering the rod through the 1-1/2-inch hole already mentioned.

The gaskets were cut from shoe-sole material 1/4 inch thick, and weather-strip adhesive was used to insure the tightness of the seal between the gasket and the carbon rod. In operation, the tightness of the installation can be determined by watching the size of the bubbles rising in the water; for the tighter the connection, the smaller the bubbles and the better the conditions for the fish.



(Drawing courtesy of the author)

The other end of the oxygen supply tube is connected to an ordinary oxygen cylinder or bottle such as is used by welders. The outlet from the bottle is equipped with a pressure gauge and a volume gauge: the first gauge indicates the pressure of the oxygen flowing into the distribution tank, and the second indicates the amount of oxygen remaining in the bottle. It has been found that a pressure of 4 to 8 pounds usually is sufficient with the loads that are hauled in the smaller trucks. With the larger distribution units, however, a pressure of 7 to 10 pounds ordinarily is used; and in the larger trucks, more than one 4-foot carbon rod is installed in order to assure better distribution of the oxygen.

Each truck is equipped with a rack that will hold more than one oxygen cylinder at a time, so that there is always a standby supply if needed. Although the trucks are still equipped with a pumping unit to use in emergency, or to agitate the water sufficiently to liberate the noxious gases produced by the fish, so far no difficulty has been experienced with any part of the oxygen unit. Different pressures of oxygen may be needed, depending upon the number of fish being hauled or the water temperature in the tank. Obviously, the greater the temperature of the water, the greater the amount of oxygen that may have to be introduced, as the warmer water is incapable of holding so much dissolved oxygen as water of a colder temperature. It has been noted, too, that less oxygen is required for fingerling fish than for adults.

Loads of more than 300 pounds of fish have been hauled in the small tanks with no difficulty for as long as 6 hours. For shorter periods, these small tanks have hauled 500-pound loads with no difficulty. In the larger tanks, which have approximately 3 times the water capacity of the small tanks, loads exceeding 750 pounds have been hauled.

Although these determinations are not so scientific as might be desired, oxygen requirements can be determined by watching the fish during transportation. If the oxygen pressure is increased slightly at the first signs of distress, ordinarily the fish will show a favorable reaction within a very few minutes. It is possible to "burn" the fish with too much oxygen, but this condition has never been noted at the low pressures used. If it should occur, the fish would show marked reaction and the pressure could be reduced until they were "riding" normally. Too, foam starting to collect on the surface of the water is an indication that the water is not properly absorbing the oxygen. This would indicate that the water is too warm and should be cooled by icing or some other means.

A further suggestion: If the carbon rod is put in a recessed tank below the floor of the truck tank and covered with a brass screen, the oxygen can still be bubbled into the tank and the fish can be removed much more easily.

IMPROVED YELLOW PERCH CATCH

For several years the yellow perch in southern Green Bay (Lake Michigan) had been getting smaller, and the species had symptoms typical of overpopulation. At the same time, sportsmen and commercial fishermen were unsuccessful in cropping the annual increases in the population. Research showed, however, that the fish were dying of old age before reaching the minimum size specified as legal for the commercial fishery. Reduction of the commercial size limit by 1/2 inch permitted fishermen to keep much of their catches. Since then, the growth rate of perch has so increased that the average age of fish caught has been reduced by at least 1 year, and sportsmen's creels contain a greater proportion of larger perch.

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